TECHNICAL EVALUATION: FEASIBILITY OF A BALLISTICS IMAGING DATABASE FOR ALL NEW HANDGUN SALES

By

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Technical Committee

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1.0 EXECUTIVE SUMMARY

Summary

Automated computer matching systems do not provide conclusive results. Rather, a list of potential candidates are presented that must be manually reviewed. When applying this technology to the concept of mass sampling of manufactured firearms, a huge inventory of potential candidates will be generated for manual review. This study indicates that this number of candidate cases will be so large as to be impractical and will likely create complications so great that they cannot be effectively addressed.

1.1 Firearms Identification and Automation

The concept of automated imaging was originally developed to aid the firearms examiner in keeping track of open case files. Open case files refer to those cases in which an evidence cartridge case or bullet could not be linked to any firearms in the possession of law enforcement at the time of examination. In 1994 the Office of National Drug Control Policy (ONDCP) validated the concept of ballistics imaging of firearms evidence in the forensic science community (consisting of bullets and cartridge cases in which they could be automatically compared to evidence specimens for preliminary correlation). There are several issues associated with an automated imaging concept that have to be considered. These relate to issues that impact the efficacy of the use of ballistics imaging when applied to large numbers of commercially produced firearms. These are:

1. Current imaging systems require trained personnel, ideally a firearms examiner, for entry, searching and verification. The use of technicians typically results in higher numbers of false positives that need to be microscopically compared.

2. Current systems may not be as efficient for rimfire firearms and are limited to auto loading weapons. Proposed systems will not practically accommodate revolvers, rim fires, certain shotguns and rifles. A large proportion of firearms sold in CA may never make entry into the system.

3. It is unknown at this time whether or not the algorithm can successfully ID a cartridge case fired after typical break-in and wear have occurred back to the #1 casing fired at the time of manufacture. Performance Test #7 (See page 8-11) showed that even in a limited database, the ranking of subsequently fired casings could drop enough to fall from a candidate list for consideration. Typically quoted existing research/papers regarding persistence of fired marks on fired cartridge cases were written based on manual comparison by qualified firearms examiners, not automated correlation techniques.

4. All potential “hits” selected for further inspection by computer correlation must be confirmed by “hands on” microscopic examination by a qualified firearms examiner.

5. Firearms that generate markings on cartridge casings can change with use and can also be readily altered by the user. They are not permanently defined identifiers like fingerprints or DNA. Hence, images captured when the firearm is produced may not have a fixed relationship to fired cartridge casings subsequently recovered.

6. Cartridge casings from different manufacturers of ammunition may be marked differently by a single firearm such that they may not correlate favorably.

7. As progressively larger numbers of similarly produced firearms are entered into the database, images with similar signatures should be expected that would make it more difficult to find a link. Therefore, this increase in database size does not necessarily translate to more hits.

8. Fired cartridge casings are much easier to enter, correlate, and review than fired bullets.

9. Not all firearms generate markings on cartridge casings that can be identified back to the firearm.

1.2 Current Use of Automated Ballistics Imaging by Law Enforcement Agencies

Automated ballistics imaging systems are currently in use by many law enforcement agencies (LEA). These systems are called DRUGFIRE™ and IBIS©, both of which operate under the acronym of National Integrated Ballistics Information Network (NIBIN). A recent MOU between the FBI and the BATF dictates that only the IBIS system will continue under the NIBIN banner. The NIBIN systems provide “cold hits ”[1] or a link between two or more crimes. These cold hits are much more frequent in large urban areas. One reason for this is believed to be that firearms used in gang crimes are frequently passed around by gang members, reused in crime and are subsequently available for linkage. Cold hits provide an investigative lead for the investigator; they do not necessarily implicate any one shooter. In six years of operation, the Southern California Database has 433[2] cold hits from 338 firearms. This area covers all the major metropolitan areas of all Southern California. As an example, the Southern California 9 mm Luger cartridge case evidence database size has 3,422 evidence cartridge cases and

[1] A “cold hit” is an occurrence in which a match between two separate case exhibits in a database is achieved which were not previously known to be related.
[2] Some of these cold hits may actually be warm hits in that there was an expectation before NIBIN analysis that they came from a common source.

10,532 test-fired cartridge cases at the time this publication was prepared. These databases are very diverse and include numerous manufacturers.

In contrast, the Sacramento County Crime Laboratory has actively developed its ballistics-imaging database since 1996 and has had 14 cartridge case cold hits with no prosecutions. The Oakland Police Department has 37 cold hits to date, one of which led to a conviction. The actual issue of cost effectiveness and related labor cost for each cold hit has not been documented nor researched. There have been no studies published that discuss the significance of a cold hit and its effectiveness.

1.3 Expectations of a California Database

In estimating the size of a potential California database, the figure of 107,791 pistols[3] entries per year has been used. This would only count semi-automatic pistols .25 caliber[4] and higher. Revolver will not be entered due to the low frequency of revolver cartridge cases found at crime scenes. After five years there will be an estimated 538,955 registered pistols in this database. Of these, about 242,500 handgun entries will be in the 9 mm Luger cartridge category. This would still represent a very small fraction of all the handguns in circulation.

Recent legislation under California Penal Code section 12125, et seq., (SB 15 Safe Handgun bill) may reduce the variety of manufacturers that can sell handguns. This will cause more uniformity and less diversity in the cartridge case database. Essentially, there will be many more cartridge case specimens for an approved-for-sale model by a particular manufacturer. Even if the database is localized to specific regions of the state, one can readily expect to find 700+ registered handguns from one model and manufacture in a rural county with a population of 550,000 people. Consequently, metropolitan areas are expected to have much higher numbers of similar handguns than is currently found.

1.4 Limitations of the Performance Tests

In order to test a larger database, 792 California Highway Patrol (CHP) Smith & Wesson model 4006[5] pistols were test fired with a variety of .40 S&W ammunition. The performance tests in this study were designed to mimic what would happen when a database is substantially increased in size. The results obtained from these tests are not reflective of what is currently obtained by the local LEA's. Current California Law Enforcement Agency (LEA) databases are much smaller and more diverse. Even in the current Southern California database of 3,422 - 9mm cartridge cases, it is extremely unlikely that there would be 792 incidents of evidence cartridge cases fired by one

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[3] Estimate given by the DOJ Firearms Division based on new sales for the period 1997-2000.
[4] Rim fires are not considered at this time. Although they can be imaged in NIBIN, the utility of such imaging for unique individual characteristics has not yet been independently verified.
[5] These were scheduled to be issued to CHP Cadets and most were in new condition.

caliber, manufacture and model. However, for a database of newly sold handguns, one could expect to see several times this number in the highly populated areas.

For automated imaging, a cartridge case can be preliminarily identified from its breech face markings and/or firing pin impressions. In order to simplify potential identification selections, one would like to have both breech face and firing pin impressions rank high. These tests looked at correlations and positions of fired test cartridge cases compared to specimens known to be in the database. Ideally the test/evidence cartridge case should be in the first rank.

1.5 Results of the Performance Tests

The performance tests have provided some results that indicate both the potential and limitations of a statewide database. Most of these results have not been mixed in a current real-life database. The combination of this test database and a current real-life database would have improved the information about correlation performance.

Computer Capability and Speed

The IBIS system appears to have the potential to be scalable and should be capable of operating with a large California database. This would not be for real time analysis since each search of a hypothetical 100,000-cartridge case database would require 1.5 hours using current hardware.

Effect of Cartridge Case Ranking and Database Size

As a database was increased in size by a factor of 7 (100 to 700), the position or ranking of test-evidence cartridge cases, initially in the 1st ten ranks, would change (with one exception) to undetectable ranks. This change in rank could be sufficient enough that an examiner might not link the test/evidence cartridge case to one in a larger database. If the test/evidence cartridge case was in the first or second rank, it had a tendency to stay in these ranks when there was a four-fold increase in database size. The interpretation of this is that one would like to see a cold hit in the 1st or 2nd position (rank) for large databases.

Comparison of Cartridge Cases from the Same Manufacture

The system looked at 50 duplicate test fired cartridge cases selected at random from the 792 Federal cartridge cases in the database. The results for these same ammunition tests are as follows:

- 38% were missed and not in the top 15 ranks.
- 48% with either the breech face or firing pin were in the 1st rank.
- 62% with either the breech face or firing pin or both were in the top 15 ranks.

Comparison of Cartridge Cases from the Different Manufactures

The system looked at 72 test fired cartridge cases using different ammunition and fired from random CHP guns. The results for the different ammunition tests are as follows:

- 62.5% were missed and not in the top 15 ranks.
- 22.2% with either the breech face or firing pin in the 1st rank.
- 37.5% with either the breech face or firing pin or both in the top 15 ranks.

The reason figures are quoted for 1st rank and the top 15 ranks is that one may want to use the percentages for the 1st rank with large databases in order to more accurately estimate cold hit rates. Database size can become a key issue for potential identifications.

This performance test illustrates the effect that the change of a cartridge can have on the perceived signature or image of a breech face or firing pin. Different cartridges can have this effect on the apparent signature because the impression may not mark in a similar manner with the same level of detail[6]. The algorithm is still doing its basic job of identifying similar images, thus the algorithm cannot be faulted for its lack of identification if the apparent image is different. By increasing image quality or correlating images with different illumination methods there exists the potential for improving the algorithm hit rate.

Altered Breech Face

Changing the signature of a breech face or firing pin impression for one of the CHP handguns used in this study was a relatively easy affair. The minor alteration required less than 5 minutes of labor to change the signature of the breech face and firing pin. This change is sufficient to make the cartridge case breech face unrecognizable, by IBIS algorithm, to the first set of cartridge cases test fired from that same pistol. This type of effort has happened in actual laboratory casework.

Longevity Study

Two non-CHP handguns were used to determine the effect of multiple test firings on the persistence of cartridge case impression signatures. Six hundred rounds were test fired from each of these two handguns. There is some indication of signature degradation as one compares test #600 to test #1, but no definitive conclusions could be made. In the future, further evaluation of several of the database test handgun cartridge cases that ranked in the upper 10 rankings should be used for such a test.

1.6 Interpretation of Results

It should be noted that this study looked at the cartridge case hits in the first fifteen ranks. In actual practice, when examiners are trained on the IBIS system, they are trained to only look at the first 10 ranks.

Cartridge Case Hit Rate

The California system will be working with large databases. As this is the case, the statistics that should be applied are from Performance Test 1C (correlation position and DB size) and Performance Test 3 (different cartridge ammunition).

[6] Furthermore, some primers in new cartridges may have similar manufacturing marks on them that could be construed as coming from the breech face of a firearm.

- The effect on correlation position, as illustrated in Performance Test 1C, Figure 8-7, appears valid for a larger database. Cartridge cases that are not in rank one may not be detected as the database of similar handguns dramatically increased in size. Thus the most meaningful results are those specimens in the first rank.

- Using the data from Performance Test 1, Figure 8-1:
  - 48% of the cartridge cases ranked in the number one position in either breech face or firing pin.
  - 62% of the cartridge cases ranked in the top 15 positions in either breech face or firing pin.

- Using the data from Performance Test 3, Figure 8-9:
  - 22.2% of the cartridge case ranked in the number one position in either breech face and firing pin.
  - 37.5% of the cartridge cases ranked in the top 15 positions in either breech face or firing pin.

- 78% of the evidence cases that should have a counterpart in the proposed database may not be detected when different cartridges are used. This is based on the performance of the cartridge cases test fired with CHP firearms when different ammunition was used.

- A **significant deterioration** of correlation results was observed when **one** factor was incorporated into the control performance test (Performance Test 1). Additional factors that may also have detrimental effects to Performance Test 1 include, but are not limited to:
  - Human errors – The listed performance test results did not include any effect of human error. Computer correlation results will have to be screened by human operators. There exists the potential error of hits being missed by the screening operator.
  - Longevity of marks - Persistence of the markings with use and wear of the firearm
  - Database size
  - Sub-Class marks.
  - Altered breech face or firing pin.

Database Size

The proposed database size will be very large with many firearms expected to be made by the same manufacturer. At a presumed rate of 107,791 new handguns per year, from a limited selection of semiautomatic models and calibers, the database will be expected to represent:

- After five years there may be 538,955 handgun cartridge case images.

- These 535,955 handguns will still be a small fraction of the existing firearm in circulation
- About 45% of the handguns will be 9 mm Luger pistols.
- Many samples of a small variety of different handguns. A small rural county, such as San Joaquin, had 800+ handguns of one model, caliber and manufacture.

1.7 Recommendations for Further Action

Any ballistics-imaging program is complex and has many ramifications for the end user. In developing this study, other issues that should have been addressed were found. Furthermore, experimental designs could be improved in order to derive additional meaningful data. A study of this type has many variables that need to be researched and addressed. Some recommended areas for further study are as follows:

- Conduct studies using 1,000 - 9mm Luger pistols that are the same model and make and are in use by local law enforcement agencies. Ideally, they should be new if such a large number can be found.
- Evaluate this data in its own pristine database and in combination with a database from a large regional area that has a variety of different firearms.
- Conduct a longevity study to evaluate persistence and recognition of correlation related marks. Fire multiple rounds using several of the test handguns that initially rank high in the database search. Then fire 600+ rounds and conduct additional comparisons[7].
- Evaluate investigative effectiveness of "hits", what happens to a "hit" at local law enforcement agencies after it is found in the database.
- Review what "hits" enter the system for prosecution.
- Further define what are "cold hits"[8], how they are documented, and the actual number of firearms represented by the cold hits.
- Evaluate the associated costs for ballistics imaging systems including telecommunication / data lines, equipment, labor for data entry, and the related costs associated with manual comparisons and verifications by an examiner.
- Evaluate the potential number of evidence cartridge cases seized by local law enforcement agencies that could be entered into a system but are currently not entered due to funding limitations.
- Evaluate the types and sources of firearms that provide the most potential for cold hits.
- Determine the age distribution of those firearms that have been found in cold hits. This distribution can be useful to decide the length of time a state database has to be retained for active searching and if data archiving can occur.

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[7] An underlying assumption is that the average individual does not fire more than 12 boxes (600 rounds) of ammunition. In a typical practice shoot at a range, it is very common to fire 2 boxes or 100 rounds of ammunition for practice.

[8] Actual verification on whether or not a hit is actually "cold" is needed. Many agencies are concerned with good numbers, rather than accuracy. Are agencies funded by the so-called success of the automated system going to accurately represent their true cold hit statistics?

2. 0 BACKGROUND OF FIREARMS IDENTIFICATION

This section describes the background of firearms identification, the type of evidence associated with firearms, firearms statistics, manpower considerations, and test protocols.

2.1 History of Firearms Identification

The first use of the microscope as an advanced tool in firearms identification was around 1925. This was a single-eyepiece instrument similar to the microscope used today. The next advancement was the dual eyepiece ballistics microscope which is still in use today. In the late 1920's, Kodak manufactured a camera system for taking a photograph of a bullet in a panoramic view. This photographed view was intended to be stored in open case files, but the process never caught on and was discontinued in the early 1930's. There were numerous different instruments designed for the recording and storing of images of bullets for open case files that could be manually searched for unsolved cases. One particular instrument was the Striae-O-Graph, a mechanical recording device developed by John Davis of the Oakland Police Department. This recording instrument attempted to profile, by mechanical means, the striae on the surface of a bullet. However, this system and other attempts were never widely used, primarily due to their complexity and inability to store the extensive data results. Currently, except for some minor changes in optics and equipment, the technology remains essentially unchanged.

2.2 Current Case Issues

Open case files in the firearms identification area refer to those case files retained by an agency that consist of fired bullets and cartridge cases recovered from crime scenes. When bullets and cartridge cases are fired in a weapon, minute marks are left on the cartridge cases and the bullets. These marks can subsequently be used to conclusively identify the firearm as having fired these items. A firearms examiner performs the comparison of such evidence. The examiner takes the evidence bullets or cartridge cases and compares them using a bullet comparison microscope to test fired specimens from a suspect weapon. The current procedure for determining whether or not a recovered firearm was used in one of these cases is time consuming. This comparison can usually take 4 hours or more depending on the difficulty of the marks and degree of documentation required. The examiner is required to physically remove the evidence from a vault, place the test and evidence bullets/cartridge cases on a microscope, and perform an optical comparison. While on the surface this does not seem significant, there are considerable logistical problems. These open case files can number in the thousands for the larger agencies and are located over a broad geographical area. Following the chain of custody requirements alone makes it impractical to routinely analyze such evidence. Furthermore, the tiem needed for microscopic comparison makes this procedure all but impossible.

It was this time consuming situation that led to the development of automated imaging of firearms evidence. This procedure had its beginnings with the use of an imaging system that took pictures of cartridge cases and initially compared such images visually in a comparison mode on a computer. The images were classified on the basis of various class characteristics to narrow the number of possible candidates.

2.3 Developments of Automated Systems

In 1994 the Office of National Drug Control Policy (ONDCP) conducted a study[1] as to the feasibility of automated imaging systems that could retain information and images of fired cartridge cases or bullets. This study produced an extensive publication that discussed the feasibility of such systems. This study found that in the context of databases used by local agencies, such systems were feasible and could subsequently compare these images in an automated fashion that would revolutionize firearms identification. In fact, the forensic laboratory would now become proactive and provide investigative leads to the investigator. Such a system would not be expected to, nor could it provide positive identifications. However, the system would provide a needed service if it could narrow the likely choices in open case files from many to a few.

At the time of the study, two systems were in place. BULLETPROOF© (BP), manufactured by Forensic Technology Inc. (FTI) was supported by the Bureau of Alcohol Tobacco and Firearms (BATF). The other system was DRUGFIRE™ (DF) and it was developed by and supported under contract by the FBI using MSI Inc. as the contractor. BP looked at bullets and DF looked at cartridge cases. The tests were not able to perform a direct comparison of the algorithms of both instruments since they each looked at different specimens. However, BP and DF were able to make valid comparisons as to the feasibility of such systems and the proper use of network technology which is critical if these systems are to be used over a wide area. These instruments, in their infancy, made a major breakthrough in the recording, storage, and retrieval of minute markings on the surfaces of fired bullets and cartridge cases. These systems have made it possible for the firearms examiners to automate a portion of firearms analysis. The ONDCP study made several recommendations for improvement; some of these were incorporated and some were not. In November 1994 FTI came out with BRASSCATCHER© for the analysis of cartridge cases. Subsequently, the BRASSCATCHER© and BULLETPROOF© systems were referred to as the Integrated Ballistics Identification System (IBIS). About two years later, the FBI and its DF system developed a bullet identification system with an analyzer known as a ROTOSCAN.

2.4 Description of Firearms Evidence

When a gun is fired, a series of events occurs which results in marks being imparted onto the bullet and cartridge case. Generally, the firing pin strikes the primer to

[1] Bench Mark Evaluation Studies of the BULLETPROOF and DRUGFIRE Ballistics Imaging Systems, Office of National Drug Control Policy November 1994

initiate firing. The general shape of the firing pin tip as well as the minor imperfections of the firing pin is stamped onto the primer.

The burning powder (a deflagration) creates an extreme pressure which forces the bullet out the barrel. The bullet, under great pressure, conforms to the shape of the bore as it engages the rifling. Microscopic imperfections in the bore result in the bullet receiving striations ("striae") as the bullet passes through the barrel.

The expanding powder gases that force the bullet out the bore also force the cartridge case to expand inside the chamber as well as to the rear. The resulting marks imparted on the cartridge case include chamber marks on the side of the cartridge case and breech face marks on the head and primer area.

On semi-automatic and automatic firearms, a hook-shaped device called an extractor will extract the fired cartridge case out of the chamber as the action is opened. The result will be extractor marks imparted onto the cartridge case rim area. The ejector, which causes the cartridge case to be flipped/ejected out of the action, will also impart markings on the head of the cartridge case.

Firearms evidence markings on bullets and cartridge cases consist of class and individual characteristics. Class characteristics are those characteristics imparted to a bullet or a cartridge case that represents a family of firearms and usually are limited to a group of manufacturers. Thus class characteristics by themselves are useful, in that they can reduce a large database down to a more manageable level. Individual characteristics are those marks, including straie and other imperfections, which make a particular fired bullet or cartridge case unique and serve as the basis for a conclusive identification to a particular firearm.

2.4.1 Cartridge Cases as Evidence

Different marks are left on the cartridge case when it is fired in a revolver or semi-automatic firearm. The most prominent marks are usually left on the soft primer of the fired cartridge case. These impressions, identified as breech face and firing pin marks can be unique to a firearm and can cause the cartridge case to be conclusively identified to a particular firearm. In fact, the breech face marks on the base or primer area are usually prominent and will remain the same for the life of the firearm, unless action is taken to modify the breech face. Other marks on different areas of a cartridge case can also be used to identify the cartridge as having been fired in a particular firearm. At crime scenes, cartridge cases by their very nature are seldom damaged and are usually recovered in good condition. The areas used for identification are generally not damaged at the crime scene.

2.4.2 Bullets as Evidence

For fired bullets, the lands, grooves, and diameter of the barrel impart the class characteristics on each bullet fired through that barrel. These are recorded as the caliber, number of land and groove impressions, direction of twist, and the land impression width. The unique marks that identify a bullet to a particular barrel are usually located in the land impression areas. These marks, or striae, can vary throughout the life of a firearm. In some firearms[2] these marks are sufficient to match bullet #1 to bullet #5000. In other firearms, these marks cannot even be matched to consecutively fired bullets. Copper jacketed bullets fired from semi-automatic handguns and revolvers can usually be identified to a particular barrel for a substantial period of time and are generally easy to identify; however, bullets fired in some of the poorly manufactured revolvers can at times be very difficult to identify.

In the firearms identification, the most difficult analysis (other than .22 caliber bullets) is the identification of damaged bullets fired from loose fitting or poorly aligned revolvers, particularly when lead bullets are involved. Lead bullets fired in revolvers and semi-automatic pistols can be very difficult to compare after they have been damaged. In particular, the base portions of such bullets usually have striae removed by the effects of heat and gas cutting. Bullets fired from .22 caliber firearms are notoriously difficult to identify because of deformity and damage.

Bullets recovered from crimes scenes and from the human body are usually distorted and damaged. This damage is variable and can range from minimal to extensive. This damage does not necessarily preclude an identification of such bullets because only a very small striated area may be needed to conclusively identify a bullet. However, the damage does complicate the analysis and will generally make examination much more difficult. As a rule, bullets take much longer to identify than cartridge cases.

2.4.3 Value of Cartridge Case or Bullet Evidence

Both types of evidence have their strong points and weak points. As a general rule, cartridge cases will provide evidence from semi-automatic handguns, shotguns, and rifles. When revolvers are used, cartridge cases are generally not recovered from a crime scene. Bullets fired at crime scenes from semi-automatic handguns and revolvers can be found if they remain in the body or some structure; however, shotguns and many .22 caliber weapons will generally not leave projectile evidence suitable for the comparison microscope. Furthermore, it is typical to find cartridge cases but not the corresponding bullets at crime scenes. There are no detailed statistics on the ratio of the different types of firearms evidence recovered nationwide; however, there are statistics that can be used to infer the types of weapons used in crimes.

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[2] Comparison of 5000 Consecutively Fired Bullets and Cartridge Cases from a 45 caliber M1911A1 Pistol by Yoshimitsu Ogihara et al, Association of Firearms and Tool Mark Examiners Vol 21 #2 April 1989.

2.5 Identification Issues

An automated ballistics imaging system does not conclusively identify a cartridge case or bullet. It only lists those most similar to a given evidence or reference specimen in the database. If a cartridge case in the database has no strong microscopic features, it will match very well to any cartridge cases that likewise lack any significant detail or features. It must be kept in mind that the toolmarks on a cartridge case or bullet are not like DNA or fingerprints. Over time and if subject to wear or abuse, the marks can change. Many of the cartridge case identifying marks are considered impression type toolmarks. These marks have a tendency to be stable for some time. Bullet marks are considered striated toolmarks and are more susceptible to change over time with use. A qualified firearms examiner using a high quality bullet comparison microscope (Illustrated in Figure 1)

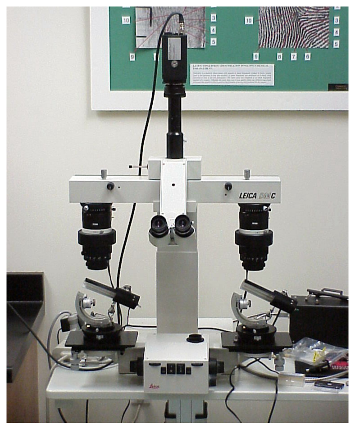


Figure 2-1. Leitz Firearms Comparison Microscope

currently performs the final identification process for cartridge cases and bullets. In the case of cartridge cases, this identification can be made on areas other than the breech face. The confirmation by the comparison microscope will, for the foreseeable future, always be the case. This analysis on the comparison microscope and the subsequent peer review of typical completed cases can take anywhere from 4 to 15 hours per case.

2.6 Subsequent History of Competing Imaging systems

In 1996, the National Institute for Standards and Technology (NIST) developed specifications for uniform cartridge case images such that both BRASSCATCHER© and DRUGFIRE™ systems then in use could share images of their databases. These specifications were never adopted. In 1996, the FBI made an announcement that they had signed an MOU with the BATF and that the two systems would eventually merge and a new National Integrated Ballistic Information Network (NIBIN) system would become the de facto standard. In reality the current database in DRUGFIRE™ is not amenable to the IBIS© system. Thus the current DRUGFIRE™ users will only be able to use their legacy systems and the corresponding database for one or two more years pending support by the FBI. As their DRUGFIRE™ systems are replaced with IBIS©

systems, the users enter new evidence on the NIBIN system and gradually phase out their DRUGFIRE™ units. A key issue in this case had been the fact the FBI used oblique illumination for cartridge case illumination, much as used by firearms examiners at their comparison microscopes. Furthermore, for database correlation, DRUGFIRE™ looked only at the breech face marks and not the firing pin impressions. Oblique illumination brings out more highlighted detail, but for database purposes is subject to operator variability. The oblique illumination method usually requires two breech face images at 90-degree orientation.

The IBIS©-NIBIN system uses radial illumination and correlates as separate images both the firing pin and the breech face impressions. The IBIS© radial illumination may bring out flatter detail, but it is less subject to operator variability, is independent of orientation, requires less training, and only needs one image for the breech face and one for the firing pin. This type of illumination is better for some of the firing pin impressions. Consequently the firing pin can now be used for correlation.

3.0 ISSUES AFFECTING CARTRIDGE CASE IDENTIFICATION AND THEIR IMPACT ON BALLISTIC IMAGING DATABASES

3.1 Identification of Fired Cartridge Cases

When a cartridge is fired in a firearm, force of ignition will cause the firearm to leave various identifying marks on the cartridge case. These marks can be class, sub-class or individual characteristics[1]. Class characteristics are features that indicate a restricted group source and result from design factors. Sub-class characteristics are features made during the course of manufacturing that further restrict the group source. On a fired cartridge case, sub-class characteristics can be mistaken for individual characteristics. Individual characteristics are those marks that serve to uniquely identify the cartridge case to only one gun. These marks can be made on different parts of the cartridge case by various parts of the firearm. The location of these marks are illustrated in figure 1 and represent the ideal situation where all such marks are present.

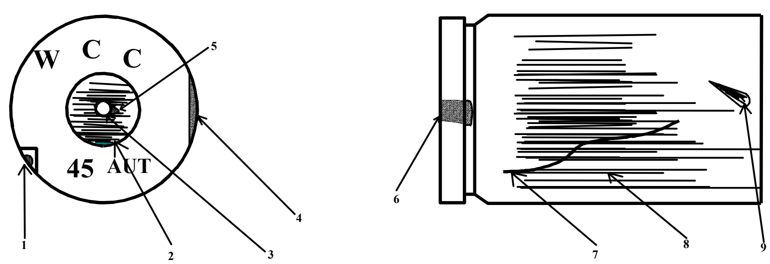


Figure 3-1. Marks on a cartridge case fired from a semiautomatic handgun

Area	Impression Type
1	Ejector Impression
2	Breech face Impression
3	Firing Pin Impression
4	Extractor Override Mark
5	Firing Pin Drag
6	Extractor Mark
7	Magazine Marks
8	Chamber Marks
9	Ejection Port Marks

[1] Appendix A. Abstracted Glossary.

The firearm examiner can use any of these marks for identification; however, in most cases the areas used for identification are the following: breech face marks, firing pin impressions, extractor or chamber marks. For automated imaging, the only areas used for analysis are the firing pin impressions, breech face marks, and ejector marks. These are the marks that are typically repeatable and amenable to routine imaging. In most cases the firing pin may not leave sufficient detail for analysis and most examiners rely on the breech face marks.

3.2 Breech Face Issues

The detail of these breech face impressions is dependent on cartridge chamber pressure[2] and the type of breech face manufacture/condition. Lower pressure cartridges are not expected to consistently produce decent breech face impressions. Dirt or lead build up on the breech face can reduce the detail of breech face impressions. An example of semi-automatic pistol breech face detail is illustrated in figure 3-2.

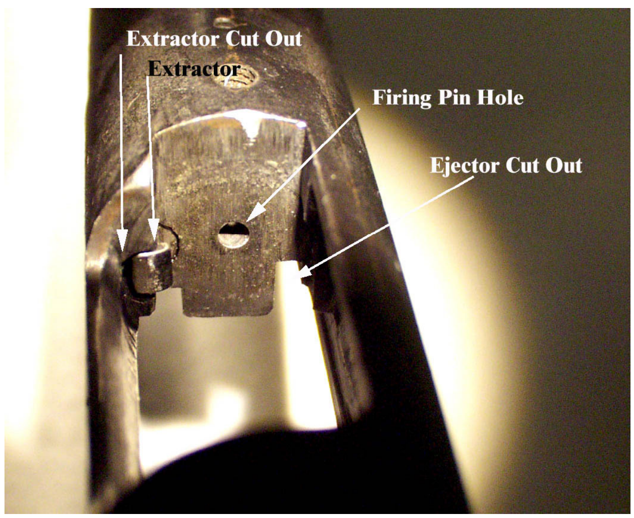
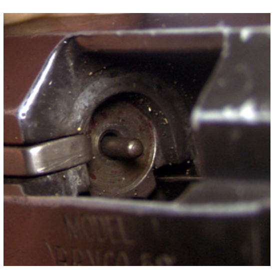
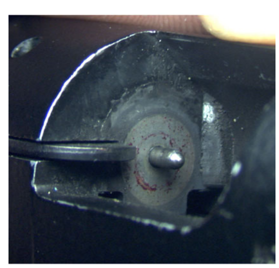


Figure 3-2. Breech Face from a .45 ACP Semi-Automatic Pistol

Examples of different breech faces are illustrated in in Figure 3-3.


Bryco breech face


Glock breech face


Lorcin breech face

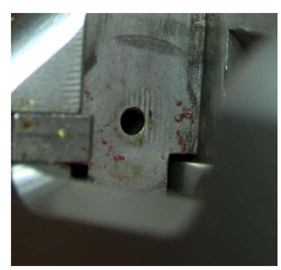

S & W breech face

Figure 3-3. Breech Face Types

[2] Chamber pressure within a single caliber can vary and depends on factors such as the bullet weight, powder charge, powder type, dirty barrel, oversize bullet, deep grooves, polygonal rifling etc.…

These photographs illustrate the fact that the breech face surfaces can be quite different between the various manufacturers. In particular, the Glock breech face has well-recognized characteristics. However, the surface finish of a breech face is highly dependent on the manufacturing method. Most manufacturers use similar types of tooling processes when finishing a breech. A key assumption is that this tool leaves individual marks that are unique to each breech face. However, there could also be sub-class characteristics that are not unique to a single gun and these sub-class marks can carry over to many breech face surfaces. The S & W breech face (Figure 3-3) illustrates some marks that could be sub-class characteristics and would not necessarily be unique. The amount of surface detail transferred to a cartridge case can also be affected by the amount of debris buildup. The Lorcin breech face (Figure 3-3) illustrates the problem of debris build up, which can reduce the breech face detail. The detail that may be impressed on a breech face can also vary with the type of cartridge manufacturer.

3.3 Ammunition Effect

Another variable in the production of breech face marks is the type of ammunition used. The detail left on a cartridge case is also dependent on the cartridge chamber pressure, bullet weight and the hardness of the primer. On some occasions, these can vary to such an extent that an examiner will not be able to identify test 1 to test 2 when different ammunition is used in the same gun. One of the cardinal rules in firearm examination is to test fire the gun with similiar ammunition as the evidence ammunition if at all possible. Illustrations of various pistol cartridge case impression variations are depicted in Figure 3-4.

These pictures illustrate that some firearms will reproduce well with sufficient detail, while some firearms will vary in their reproducibility depending on the cartridges used. Firing pins can be relatively smooth and nondescript. In such cases, these smooth firing pin marks can serve primarily as a class characteristic indicator. Even when they have gross features such as in the Bryco, these could be class or sub-class characteristics. An exception is the Glock firearm with its characteristic firing pin drag and aperture marks. This is one of the reasons that cartridge case examinations frequently involve the examination and comparison of other unique marks such as chamber marks, ejection port marks, ejector marks, and rimfire anvil marks. The impressions are not only dependent on the hardness of the primer, but also on how well the primer seats in the local cartridge case. In smaller databases these issues may not be significant, but with a large database using newly manufactured firearms, these differences can prove significant.


R-P cartridge from a Glock


Speer cartridge from a Glock


Wolf cartridge from a Glock


W-W cartridge from a Glock


W-W Subsonic from a Glock


R-P cartridge from a S & W


Speer cartridge from a S & W


Wolf cartridge from a S & W


W-W cartridge from a S & W


W-W subsonic from a S & W


R-P cartridge from a Bryco


Speer Cartridge from a Bryco


Wolf cartridge from a Bryco

Figure 3-4. Breech Face Styles

This aspect is one reason why it is important to test the performance correlation of any database with different cartridge cases because one cannot be assured that the evidence cartridge will be fired using the same type of cartridge as the test specimen.

3.4 The Issue of Sub-Class Characteristics

The issue of sub-class characteristics is especially relevant to the area of breech face impressions. In essence these characteristics frequently are misidentified as individual characteristics by the inexperienced examiner when in fact they can belong to a large group of firearms. A textbook case of this possibility was discussed[3] by P. Lardizabal when he compared two Heckler & Koch USP pistols. The reason that these sub-class characteristics carry over to multiple weapons is that the breech faces are stamped[4]. This is common with some of the less expensive firearm such as Lorcin, Phoenix Firearms, and Davis. A further article by W. Matty[5] is illustrative because the two-breech faces matched on the DRUGFIRE system even though they were subsequently proven not to have been fired by the same firearm. It appears that a solid stamped steel insert is placed into a non-ferrous alloy slide. The stamping marks can carry over from one steel insert to another. This steel insert has surface sub-class features that could be

[3] Lardizabal, P., "Cartridge Case Study of the Heckler & Koch USP", AFTE Journal, Vol. 27 #1, January 1995.
[4] Thompson, E., "False Breech Face ID's", AFTE Journal, Vol. 28, #2, April 1996.
[5] Matty, W., "Lorcin L9mm and L380 Pistol Breech Face Toolmark Patterns", AFTE Journal, Vol. 31 #2, Spring 1999.

mistaken for individual characteristics. In 1997, J. Miller[6] also wrote an article describing in detail the various manufacturing processes at Lorcin.

The key issue in this regard is that certain manufacturers have methods of producing breech faces that negate their effectiveness for use in ballistic imaging. These breech face marks may look unique and individual when in fact they are not. In an automated imaging system, this would result in a series of false hits.

[6] Miller, J. "Manufacturing the Lorcin L380 and Corresponding Characteristics", AFTE Journal, Vol. 29 # 4, Fall 1997.

4.0 THE CURRENT NIBIN-IBIS BALLISTICS IMAGING SYSTEM

4.1 Integrated Ballistics Identification System (IBIS™) Description

The current ballistics imaging systems are used by police agencies to enter firearms evidence such as cartridge case and bullet images from criminal cases. These images are then compared to images from test-fired weapons that have been entered by various police agencies from seized or recovered firearms.

The stand-alone Integrated Ballistics Information System (IBIS™) manufactured by Forensic Technology Inc. (FTI) consists of a Signature Analysis Station (SAS) and a Data Acquisition Station (DAS), which obtains the data. The SAS receives images from the DAS and performs all the computer intensive labor such as correlations and has the capability to network with one or more DAS or DAS/Remote stations. In essence, the SAS serves as a server for a local or Wide Area Network (WAN) system. The current SAS consists of a client computer connected to a Silicon Graphics Origin 200 server with one or two processing chips; however, FTI is also using a Silicon Graphics SGI Origin 2400 computer with 16 co-processors with large scale database projects.

In California, as part of the BATF-FBI MOU, all ballistics imaging systems are undergoing conversion to IBIS© DAS/Remote (RDAS) systems with two central servers located in the BATF Walnut Creek office. These servers will handle the current ballistics imaging systems from all the local law enforcement criminalistics laboratories that are participating in the program.

The Remote DAS (RDAS) currently has the capability to document and enter bullet and cartridge case images. In the analysis of a cartridge case image, the cartridge case is placed in a holder, illuminated with an annular ring light source and is imaged with a solid state CCD sensor. One image is taken of the breech face and another image at a different magnification, is taken of the firing pin. The software partitions the total breech face image into two separate images as illustrated in Figure 4-1.

Figure 4-1. Breech Face Image Selection by the DAS

The breech face image consists of the donut-shaped area on the primer less the contents of the firing pin image. (The image breech face area is between the large and small white circles in Figure 4-1). The firing pin image is within the white small circle surrounding the firing pin. Both of these images are correlated separately and receive their own score and ranking in the database. Thus the operator will see a breech face image with a score and a candidate match. Likewise there will be a separate score and candidate match for the firing pin impression. When a hit is obtained, either the firing pin or breech face can rank in the 1st position. If one of these images lacks sufficient detail, then the ranking could be different between firing pin and breech face in that one may rank 1st and the other in a different position. The score basically provides a ranking in the correlation; however, the absolute values of the scores are not that significant. What is significant[1], is if the first score is somewhat higher than the subsequent scores. If this is the case then the operator has a good indication of a candidate hit. If the scores are close together, then this may indicate similarity in the different images or lack of sufficient detail to distinguish the images.

4.2 Image Analyses and Correlation Algorithms.

The images that are taken consist of high-resolution digital gray scale images or pictures. Digital images can be processed by various mathematical formulas to achieve certain desired effects. Some of these mathematical formulas or algorithms have the capability to look at an image and depict its contents in a mathematical model. This is known as a correlation algorithm. These types of calculations are complex and mathematically intensive. They require extensive computational power. It was not until the last 10 years with the advent of the more modern computer that these types of calculations could be performed on the every day computer. In fact the early IBIS system studied by ONDCP in 1994 used a 486 PC type computer.

As the FTI describes the process, "The image as such is not correlated. Upon completion of the acquisition process, significant information is extracted from the original image. This information is called the "signature" and corresponds to a mathematical representation of the image. The correlation algorithm is comparing those signatures using a series of mathematical computations.

What is important to keep in mind is that while computer speed and computational power have made dramatic improvements in the last 10 years, the image algorithm is independent of this improvement. Its improvement is limited by the skill of the mathematician. Faster computers only enhance the calculation speed of the algorithm.

For an image comparison to be successful, cartridge cases must have reproducible detail that is unique to each image or cartridge case. If a series of cartridge cases have minimal or no detail in the breech face marks/firing pin impressions, the images will have

[1] Per the IBIS ™3.3 training manual "Introduction to IBIS™", when interpreting correlation results for cartridge cases look for the largest gap in scores. The gap is a "jump" in the progression when scores are sorted in descending order and can sometimes help determine which candidates compare. If no gaps are noted then compare at least the first top 10 positions for breech face, firing pin and ejector mark scores.

insufficient information to allow the algorithm to properly perform its task. In essence, the algorithm should have no problem separating images with gross features such as the Bryco and the Glock breech face marks. When cartridge cases with the same overall breech face marks are analyzed and the system has to evaluate the fine detail, then the image algorithm really has to perform its function. By their very nature, some cartridge cases are much easier to compare than others. The Glock cartridge case, in particular, is generally easy to identify because of its strong breech face impression, firing pin aperture marks, firing pin shape, and striated detail.

4.3 DAS Acquisition Specifications

The process of capturing and transmitting images requires a high bandwidth network if the system is to function in a fast response time. Most networks consist of a T-1 or fractional T-1 lines between the DAS and the server. The only exception to this is the Rapid Brass Identification (RBI) system, which consists of a laptop and microscope and can be used to capture images in remote locations. These images are subsequently transmitted by modem or Local Area Network communications to a DAS or DAS/Remote system. The DAS system takes the initial digital picture, performs its correlation of the breech face and firing pin impressions, and compresses the image for later use.

The current specification for the FTI image sizes[2] are illustrated in Table 1:

Breech Face Image	230.400 KB
Compressed Breech Face Image	22.579 KB
Grayscale Level	256
Firing Pin Image	230.400 KB
Compressed Firing Pin Image	20.169 KB
Grayscale Level	256
Textual Data	1 KB
Note: 1,000 KB = 1Megabyte	

Figue 4-2. DAS Image Specifications

The images are acquired in the large format and compressed to a propriety image similar to a JPEG image to reduce image size (i.e. 22.579 for breech face). This compressed image is the one sent back to the server. Although JPEGs compressions are considered lossy[3], they are still standard ttools used in the industry. In this case an approximate 10:1 compression is still sufficient to keep most of the essential fine detail of the cartridge image.

[2]Appendix B Forensic Technology Inc. Response to Questions

[3] Lossy is a term used to describe loss of resolution. In JPEG type images a firearms examiner may be able to observe resolution degradation at 10:1 compression.

4.4 California Database Size Implications

Given the above data, one can estimate the hard disk requirement for just the image data on a potential California database. The combined Firing Pin, Breech Face and Textual Data would be 42.7 KB. With a database size of 1,000,000 cartridge cases this would equate to a image database size of about of 42.7 Gigabytes.

4.5 Correlation Times

The issue of correlation times with a large database can be significant. Correlation time refers to the time it takes the computer to correlate a test specimen and then search the entire database for an image that may or may not match. These are mathematical intensive operations and are the reason why sophisticated computer capabilities are needed. On the current IBIS-NIBIN system, the correlations are performed after replication that is set at pre-determined intervals varying from 2 to 12 hours depending on specific site needs. The correlation times can be tested on the current SAS-DAS systems; however, it is more likely that if FTI were to be selected for a California database, they might use something like the Silicon Graphics SGI Origin 2400 computer with 16 co-processors or an equivalent powerful correlation server solution. There are also other stackable configurations that can be used to perform the required computational data.

A key issue then arises as to how many times a day the local agencies may query this database with their unknown cartridge case samples. Based on information supplied by FTI, the correlation times for the SGI Origin 2400 computer are depicted in Figure 4-3.

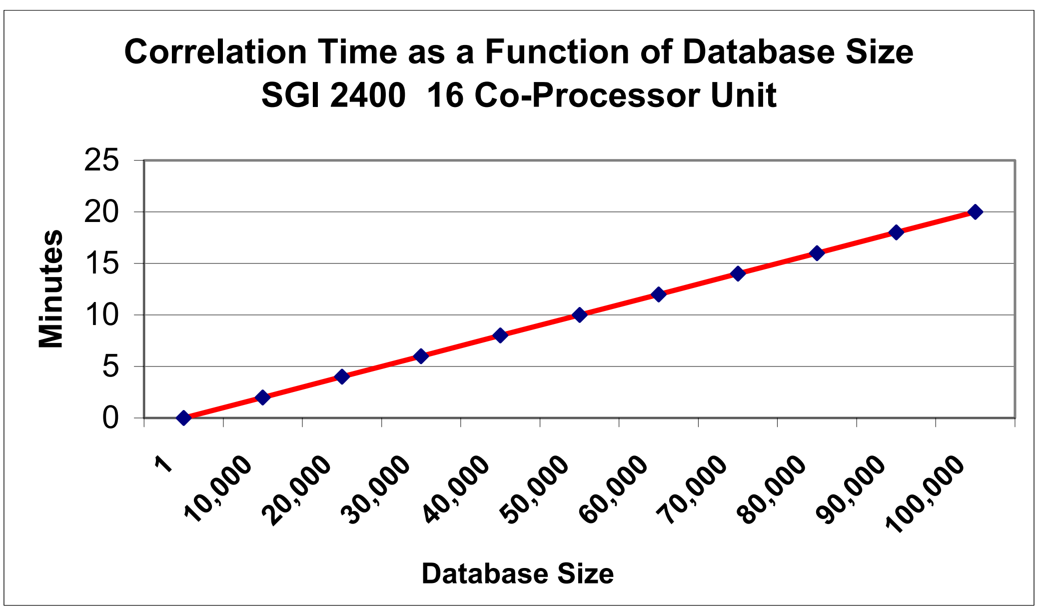


Figure 4-3 Correlation Time as a Function of Database Size

Given a five-year database size of 670,000 cartridge case records and a 9 mm Luger database size of 301,500 records alone, the time to correlate **one cartridge case** would be about **1 hour** with today's technology.

Correlation times for the other cartridge cases would be substantially less. However, the practical submission limits (using the above scenario) would be approximately fifteen 9mm Luger cartridge cases per day. These submission levels are probably adequate for the California users.

5.0 DATABASE PROFILES AND RELATED ISSUES

5.1 Southern California Law Enforcement Group Database (SOCAL)

The Southern California DRUGFIRE users group, composed of public forensic laboratories, has one of the most extensive databases in the US. Since 1994, this users group has used an integrated approach and their database covers all of Southern California. Currently they have the following specimens on file:

- Test Fired Images[1] **26,413**
- Evidence Images **7,153**
- Cartridge Case Cold Hits **433**
- Cartridge Hit Rate[2] (total entries) **1.6%**

Most cold hits are found within a single jurisdiction of the local law enforcement agency. Firearms examiners can keep the database a manageable size by removing test-fired specimens after a period of a few years[3]. Long-term database storage is only for evidence specimens from crime scenes. Cold hits frequently occur in gang shooting cases as the firearms are passed from shooter to shooter.

5.2 Sacramento County Laboratory of Forensic Services

The Sacramento County Laboratory of Forensic Services uses the IBIS system which is supported by BATF. The laboratory personnel have been inputting image data since the fall of 1996. They have had 14 cartridge case cold hits to date, 0.3% of the cartridge case image population. To their knowledge, none of these hits have led to an arrest or prosecution.

- Cartridge Case Images **2,829**
- Bullet Images **1,168**
- Evidence Cartridge Case Images **822**
- Evidence Bullet Images **300**
- Bullet Cold Hits **1**
- Cartridge Case Cold Hits **14**
- Cartridge Case Hit Rate (total entries) **0.5%**
- Cold Hit Rate **2.6 /year**

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[1] Revised data from Orange County DRUGFIRE group

[2] This is the ratio of firearm vs casing hits to the number of evidence casings in the database.

[3] The SOCAL DRUGFIRE Group has never archived test fires. They considered and were about to implement a system of archiving prior to the NIBIN transition. A crime database can have the luxury of archiving test fires. A crime gun is considered off the streets when it is taken into custody. A gun in a manufacturers database cannot be assumed to be off the street after a period of time.

5.3 Oakland Police Department Crime Laboratory

Oakland PD has been operating their IBIS system since December 1995. Their cartridge case breech face image population consists of 2,154 images:

- Test Fired Images **1,775**
- Evidence Images **379**
- Bullet Cold Hits **8**
- Cartridge Case Cold Hits **29**
- Cartridge Case Hit Rate (total entries) **1.6%**
- Cold Hit Rate **5/year**

5.4 New York Police Department IBIS-NIBIN Law Enforcement Database

The New York Police Department (NYPD) has been using IBIS since 1995. Currently, this department appears to have one of the largest IBIS based databases in existence. Their population consists of the 68,000 bullets and cartridge cases, which are broken down as follows:

- Bullet Database Size **26, 964**
- Cartridge Case Size **41,700**
- Bullet Cold Hits **7**
- Cartridge Case Cold Hits **553**
- Cartridge Case Hit Rate (total entries) **1.3%**

These results illustrate that cartridge case images are much more effective than bullets in developing cold hits. The ONDCP[4] study provides an approximate breakdown of the laboratory time requirements for the preparation, entry, test firing, documentation and review of typical bullet specimen at 84 minutes. Given that most bullets in the NYPD database were from firearms that had to be test fired, NYPD expended about 37,700 man-hours for the seven bullet cold hits. Keep in mind that a cold hit is nothing more than a linkage of two or more bullets. This linking of two or more scenes may not lead to an arrest or conviction. Given this hit rate, one must seriously rethink the use of bullets for entry into a database, except in a focused or targeted manner guaranteed to maximize the hit rate.

[4] Bench Mark Evaluation Studies of the BULLETPROOF and DRUGFIRE Ballistics Imaging Systems, Office of National Drug Control Policy, November 1994, (Page 6 firearms section)

5.5 Firearms Caliber Distribution

5.5.1 California AB635 Study

Since 1997, The California Department of Justice (DOJ) Bureau of Forensic Service (BFS) has kept track of firearms used in specified crimes outlined in Penal Code Section 12039. The year 2000 breakdown of semi–automatic handguns (in which pistols were represented 53% of the time) and excluding 22 calibers is illustrated in figure 5-1.

Cartridge Type	Percent
.25 Auto	11%
.32 Auto	4%
.380 Auto	22%
.40 S& W	11%
.45 ACP	11%
9 mm Luger	40%

Figure 5-1. Pistol Type Firearms Used in Selected Crimes

It should be kept in mind that this is a very limited database and primarily applies to the BFS service areas. It may or not may apply to the larger urban areas.

5.5.2 Southern California Profile

The Southern California group (primarily Orange, Riverside, Los Angeles, San Diego and San Bernardino cities and counties) enters only cartridge cases that are normally ejected from handguns or rifles. Their current profile is illustrated in Appendix G**.** The Southern California database size for semiautomatic handgun cartridge cases, excluding .22 calibers, is 34,629. The distribution for the following handgun cartridge cases is illustrated in figure 5-2.

Cartridge	Number	Percent
.25 Auto	5,743	16.6%
.32 Auto	1,303	3.7%
.380 Auto	7,275	21%
.40 S&W	1,648	4.8%
.45 Auto	3,886	11.2%
9mm Luger	13,954	40.2%

Figure 5-2. Southern California DRUGFIRE Group Selected Cartridge Population.

5.5.3 New York Profile

If one looks at the NYPD cartridge case database, this department enters all cartridge cases including those from revolvers, pistols and rifles. This accounts for their 41,700 cartridge case database. If one looks at only those cartridge cases left at the scene, primarily those fired from semi automatic handguns, excluding the .22 caliber handguns, the database size is about 30,008. Using this figure, one can determine the percentage of the most frequently used firearms that will be encountered in a typical crime database.

Cartridge	Evidence Cart Case	Test Cart. Case	Total	Percent
.25 Auto	659	3,831	4,490	13.2%
.32 Auto	Not Obtained.	1,303	1,303	4.5%
.380 Auto	1,667	5,235	6,902	23.9%
.40 S&W/10mm	Not Obtained	882	882	3.0%
.45 Auto	726	1,685	2,411	8.3%
9mm Luger	3,673	9,271	12,944	44.7%

Figure 5-3. New York Police Department Selected Cartridge Population

Figure 5-3 illustrates that the primary cartridge of choice in crime is the 9 mm Luger used in semiautomatic.

5.5.4 Sacramento County Distribution

The breakdown for the Sacramento County database (includes the last two years of submissions by Stockton PD) for their semi automatic handguns excluding .22 caliber is listed in figure 5.4.

Principle Semi Automatics	Number	% of Database
.25 Auto	178	10.2 %
.32 Auto	39	2.2 %
.380 Auto	295	16.8 %
.40 S&W & 10 mm	172	10.0 %
.9mm Luger	837	47.8 %
.45 ACP	202	11.5 %
Misc.	25	1.4 %
Total	1748	

Figure 5-4. Sacramento County Principle Semi Automatic Database

5.5.5 Expected California New Gun Database

Given the data from New York and other databases, it is a reasonable assumption that the single most significant firearm type in the database is a pistol chambered for the 9mm Luger cartridge. Over time this may change as the newer .40 S&W cartridge becomes more popular. Until then, one can expect that the database will be about 40 to 45% 9 mm Luger.

If the assumption is made that, every year, 134,000 semi automatic handguns are sold in California and assuming the database is retained for a minimum of five years, then the cartridge case database will number about 670,000 cartridge cases. Using the New York cartridge case population, distribution of such a hypothetical database would have the profile illustrated in figure 5-5.

Cartridge	Number	Percent
.25 Auto	102,510	15.3%
.32 Auto	25,460	3.8%
.380 Auto	159,460	23.8%
.40 S&W	19,430	2.9%
.45 Auto	56,280	8.4%
9mm Luger	308,870	46.1%

Figure 5-5. Anticipated California Database size for Selected Firearms

What this illustrates is that the 9 mm cartridge will be the key cartridge in this database. The next most significant cartridge is the .380 Auto.

5.5.6 Case Example San Joaquin County

In late 1997 a .40 S&W Glock pistol was used in a series of homicides (Peoples case) in various areas of San Joaquin County. At that time, the .40 S&W pistol chamber was a design that was fairly new to the consumer market. In order to see who might have such a firearm, a list of Glock Model 22 registered owners was generated. This list indicated that approximately 700 Glock .40 S&W Model 22 pistols had been registered in that county. The overall population of the county in 1997 was 542,000. This is indicative of the number of a single model type of a firearm that can exist in a rural county. This could easily be increased by an order of magnitude for the more urban areas of California.

5.6 Database Retention Issues

It could be argued that the database could be reduced in size by limiting the number of years that a cartridge case is retained in the database. However, at this time there has been no objective studies that address the issue of how fast a legally purchased firearm, in compliance with California point of sale laws, is used in a crime of violence. This issue is relevant to how long one may want to keep a cartridge case image in the database. From the perspective of the technical committee group, some believe a first cut at a retention time of five years is not an unreasonable estimate while some believe there should be no archiving of a manufacturer's database. In fact some of the committee members feel that if someone steals a ten-year-old gun, they are home free. They do not think a manufacturer's database should ever be archived if it is to be instituted.

5.7 Effect of Cartridge Size on Evidence Hit Rate

The issue of chamber pressure and cartridge powder charge could have an effect on both the quality of the breech face impressions and the surface area of the primer. One could logically expect that as the primer increases in size, the cartridge powder charge is increased. Or, if a heavier bullet were used, there would be more detailed breech face impressions. In a database, this would be reflected as the hit rate percentage. However, there are other variables[5] to consider such as the test fire-to-evidence ratio. Using the Southern California DRUGFIRE breakdown, figure 3-5 illustrates this percentage. These results tend to indicate an increased hit rate as the powder charge of the cartridge increases.

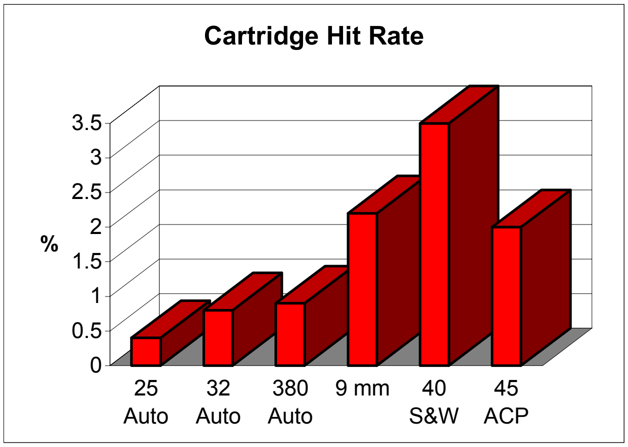

Figure 5-6. Southern California Cartridge Hit Rate as a Function of Cartridge Size[6]

5.8 Effect of Senate Bill 15 (SB15) on Database Uniformity

The current cartridge case database in California and many different states reflect a very wide variety of handguns from many different manufacturers. This broad diversity makes it possible to distinguish between firearms manufacturers and greatly eases the subsequent analyses and correlations of cartridge cases. In other words, one can spot a cartridge fired by a Glock with the naked eye.

Penal Code Section 12125 (SB15 in 1999) requires new handguns that are to be sold in California must be approved by the California Department of Justice after having undergone very stringent safety testing similar to what some police agencies use for procurement specifications if they are using the federal standard. One direct consequence of this issue is that there will be much less diversity in the newer handguns. When it comes to semiautomatic manufacturing, each manufacturer tends to use the same general manufacturing methods for their similar models.

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[5] One major factor to consider is the value of the gun to the criminal. A criminal is more likely to shoot and just throw away a cheap 25 Auto or 380 Auto pistol than a nice new 40 S&W or 45 Auto.

[6] Data provided by Orange County Crime DRUGFIRE group 9-11-01 and it is based on the number of cold hits relative to the number of test fires.

Based on the current California approved list[7] of over 550 handguns, one can expect to see primarily handguns made by fewer manufacturers. The current list shows numerous models that are manufactured by the following:

- 9mm - Thirteen Manufacturers
- 40 S&W - Twelve Manufacturers
- 45 ACP - Eighteen Manufacturers.

This list is expected to grow with time, but this list is reflective of the substantial reduction in the variety of manufacturers. There will be a smaller number of groups of similar types of breech face marks. The direct consequence will be greater uniformity of the breech face marks.

[7] http://caag.state.ca.us/firearms/

6.0 COMMENTS ON THE FORENSIC TECHNOLOGY INC. REPORT: "THE METHODS AND TECHNOLOGY FOR BALLISTIC FINGERPRINTING & THEIR PRACTICAL APPLICATIONS"

6.1 Forensic Technology Report on Ballistics Fingerprinting

The Forensic Technology Inc. report: "The Methods and Technology for "Ballistic Fingerprinting and Their Practical Applications," is a report that focuses on the aspects of making digital images of cartridge cases at the point of manufacture using a fairly sophisticated automated system. This system is called the "Virtual Serial Number System" (VSN™).

This system describes a very sophisticated and automated engineering system that has the following capabilities:

- Automated collection and transport of the fired cartridge cases to a sorter mechanism.
- Inserting the cartridge cases in a block where the cases are marked with the serial number of the firearm.
- Moving the cartridge cases to another block of 100 for entry into the imaging system.
- Imaging and correlation of the 100 cartridge cases from the manufacturer's line.[1]
- Note: The system is not designed to accommodate the evidence cartridge cases that would be submitted by local agencies.

This system may be beneficial for the large manufacturer that can test fire cartridge cases and have them serialized in an automated manner. While this aspect may help the large quantity manufacturers in submitting images, it does not address the needs of the smaller manufacturers who are not mass producers. There should be a system that they can use that is not costly. One such possibility is the FTI-RBI™ which consists of a laptop computer and a microscope which takes the proper images of a cartridge case. This system would require about 4-5 minutes per cartridge case.

6.2 System Capabilities and Cartridge Case Identification Issues

While there has been dramatic improvement in computational power due to hardware and software advances, the key issue of any identification is the capability of the algorithm to make the correlation of the cartridge cases. Correlation speed has improved with the advancement in technology but the actual linking of specimens is the issue. The algorithm that predicts a match is independent of the advancement in speed. A poor image will always be a poor image. There is a limit to algorithms based on

[1] The proposed VSN system would not rotate the breech face of the cartridge in any particular orientation. Proper orientation may be needed as an option when a database increases in size. It is also not designed for evidence cartridge case input.

photographic images in that if the detail is not there or varies between cartridge cases from the same firearm, no algorithm will be able to compensate for this type of variability. One may expect small incremental improvements to the algorithm, but it will take time and may require improved or additional imaging methods.

Furthermore, as the database size increases, one will expect to see multiple images that are similar, much like fingerprints. However, the images of cartridge cases are not unique like fingerprints. Both images will always require further manual comparison.

The comment that the "impression left on fired ammunition components during discharge are unique" should be qualified. Not all marks left on a breech face markings are unique. There is published literature about sub-class characteristic that carry over, especially on breech face impressions. The above statement also assumes that there will be breech face marks. In many cases, especially with the lower power cartridges, there may be insufficient breech face marks and the examiner resorts to other areas on the cartridge case for identification.

6.3 Database Ownership

A possibility has been expressed in centralizing the location for such a database for several states. The impact of having several states on one database may increase the "noise level" in the database. This situation could have legal and evidentiary implications. It would be akin to having the DNA or fingerprint database turned over to a private corporation. If there is to be a central database location, it should be under the direct control of a law enforcement agency having the legal authority to do so.

6.4 Functionality of the Proposed Ballistics Imaging System.

The **key issue** is the functionality of such an immense California database and the system's capability to link up evidence cartridge cases to test specimens in the database. Failure to properly perform these tasks negates the effectiveness of the database and all the cartridge case image capture mechanisms are irrelevant. While there are methods to reduce this database size by limiting searches to a geographical area[2] or using class characteristics, even the smaller geographic areas will have a substantial number of images from one series of handgun model to compare to existing images in the law enforcement database.

[2] What this would entail is that the database would be segmented in that it would search firearms sold in the area of crime occurrence. This assumes the purchaser buys the firearms in the area where they commit the crime.

6.5 Open Image Standards

The State should specify what it wants in the manner of images, resolution, format and the simple textual data. Specifications could be developed that meet the needs of the state database using the format similar to the standard[3] developed by the National Institute of Standards and Technology (NIST), published in 1996. The image would then be transmitted to the state in full format for further processing by whatever technology the state decides to use. This standard would also leave the original image available for reprocessing should a new vendor with a different algorithm want to enter this field.

6.6 Implications of an Image Hit on the Database

The system will not make a hit that is sufficient for law enforcement action. All candidate hits have to be confirmed with optical comparison by an experienced firearms examiner. Only then can the police initiate an investigation and search for the registered owner. There could be grave consequences if the police initiate an investigation before an optical comparison of the cartridge case has been made in the laboratory. Most, if not all, crime laboratories by virtue of their strict protocol will be hesitant to or may be forbidden from giving out information based only on a correlated image and not on an actual cartridge examination.

There must be accountability and security for all test fired cartridge cases. The chain of custody could play a crucial role where the only evidence is the crime scene cartridge case and the database test fired cartridge case in those cases where no firearms are located. The steps that need to be taken prior to an investigative action should be as follows:

- The local agency would have to send the evidence (fired cartridge cases) to the state.
- The test fired cartridge cases are compared on the optical comparison microscope by a qualified firearms examiner.
- A conclusion is reached and a formal report is issued.
- The evidence cartridge cases are returned to the local agency.

One should always remember that the only valid identification continues to be the optical comparison on the microscope by a qualified firearms examiner[4]. It is on this examination that search warrants and other investigative actions take place.

[3] "Specification for Interoperability Between Ballistics Imaging Systems, Part 1 –Cartridge Cases", National Institute of Standards and Technology, NISTIR 5855, June 1996.

[4] If the reverse were to happens and the test fired cartridge case, from the state database, were sent to the local agencies, it is doubtful they would have the manpower to conduct such examinations unless they were provided financial support.

7.0 DATABASE PERFORMANCE TESTS

7.1 Purpose of the Performance Tests

The purpose of these tests is to determine the feasibility of testing a large specimen database in support of Penal Code 12072.5 (AB1717). These tests will not reflect, nor are they necessarily relevant, to currently existing databases at the larger agencies. The tests that might be performed on such databases may not necessarily be indicative of how they will work on a large database, such as contemplated in California. For example, although NYPD has a database of about 4,000 - 9 mm cartridge cases, it is extremely doubtful that this database has 800 cartridges from one manufacturer and model handgun. Thus using a database of 800 similar guns (make, model and caliber) may simulate the situation when a huge database has been accumulated. The intent of these tests is to look closely at performance parameters and from the results try to predict what may happen when a database size expands to 1,000,000 cartridge case images.

7.2 Limitations of the performance tests

Given that about 45% of state wide database will be composed of 9 mm Luger cartridge cases, one would logically try to use these cartridge cases to measure a database performance. However in this case, the .40 S&W cartridge was chosen for the following reasons:

- The California Highway Patrol had about 1,000 new .40 S&W Model 4006 semi-automatic pistols on hand (Cadet new issue).
- There were convenient tests firing facilities adjacent to the firearms storage location.
- Trying to obtain multiple 9mm semi-automatics at any local police agency would have required a substantial investment in personnel time which was not feasible.

The disadvantage of the .40 S&W cartridge is that the ballistics performance of this cartridge may not be not the same as the 9 mm. Thus the .40 S&W cartridge case may not be marked in the same manner that the 9 mm Luger cartridge case will be marked. Likewise, due to resource and time constraints, other calibers, such as the 25 Auto, .380 Auto, and .45 ACP were not evaluated in these sets of tests.

The test involving the aspect of entering the CHP test specimens into an actual crime gun database was not permissible. This may have been a significant performance test.

7.3 Database Development

The .40 S&W cartridge manufactured by Federal was selected as the reference cartridge for these tests. This selection was primarily predicated on the fact that only one vendor had sufficient rounds of ammunition (3,000) that were from one lot during the initial 30-day purchase time frame. The CHP pistols were generally processed by opening one at a time, marking a coin envelope with the serial number of the firearm and the CHP inventory number. The CHP inventory number is stamped on the receiver, slide and barrel. CHP cadets fired the first 390 pistols one at a time under direct observation by BFS staff. BFS staff fired the second set of cartridge cases from about 400 pistols. When each firearm was ready for test firing, the shooter read off the CHP number to the observer. Most cartridges were caught in mid air as they ejected and those that fell on the ground were kept under positive observation until they were placed into the envelope, which was then sealed.

When the cartridge cases were numbered in the laboratory, the following procedure was used: 1) A sequential number was placed on the coin envelope, 2) this same number was placed on the cartridge case with a sharpie pen, and 3) the cartridge case was engraved with the same number and placed in another envelope with the same number. This became the test database.

7.4 Performance Experimental Description

The series of proposed tests are described in Appendix C. A committee of firearms examiners who are using either the DRUGFIRE or IBIS systems developed these tests.

<u>Performance Tests 1 - Fifty (50) Random Cartridge Cases</u>

A cartridge case database was developed containing multiple Federal cartridge cases from about 792 CHP guns. Each of these cartridge cases were labeled CA 1 to CA 792. Next, fifty (50) fired Federal cartridges, representing the second of the pair of cartridges fired for the database was randomly selected from the 792 database cartridge case sets using a random number generator. The 50 cartridge cases were labeled E 1 to E50 and were correlated against the entire CHP cartridge case database. This correlation illustrated how these cartridge cases rank in the database and provide a frequency distribution. Since this database represents a small subset of what will be a much larger database, one would like to see all the correlations place the evidence cartridges in the top positions.

Selected portions of these cartridge cases will also be used to determine correlation times as they are correlated against a progressively larger database (i.e., 1:100, 1:200 >>> 1:700). Additional analyses will take some of the lower ranking cartridge cases and have them correlated against a progressively larger (CA1-792) database to see if there is a change in correlation position or value. If there is such a change, the results could then be used to predict larger database behavior.

Performance Test 2 – Cartridges not in the Database

This portion of the study will test ten Federal cartridge cases that have been fired from the same model handgun as used for database CA1- CA792. However, these ten cartridge cases are not in that database. This test will look at the ranking levels of these cartridge cases. If the cartridge cases were to rank high as a match, this could then be an indication of the number of false hits that could be encountered as the database increases in size.

Performance Test 3 – Different Ammunition

About 22 of the CHP pistols, in addition to firing the multiple Federal rounds, also fired an additional five rounds comprised of the following brands:

- **PMC -Eldorado** 40 S&W 180 grain JHP # C40SFA Lot # ELD4oSFAQ38
- **CORBON** .40 S&W 165 grain JHP #COR4016, 1150FPS
- **ARMSCOR** .40 S&W 180 grain FMJ, Lot# 03093000
- **Remington** .40 S&W 180 grain JHP, #R40SW2C, lot # H29 NC2517
- **Winchester** .40 S&W 180 grain JHP, Sub Sonic #RA40180HP, Lot# RC41

The purpose of this test was to correlate the effect of different manufacturers on the breech face correlation. As outlined in Chapter 3, some cartridge case breech face characteristics can have substantial differences when different ammunition is used. This correlation will also be compared to the correlation in Performance Test 1.

Performance Test 4 – Altered Breech Face

A CHP pistol was fired with two rounds and then a filing alteration was performed on the breech face. After this, another two rounds were fired. The test will look at the correlation of the respective cartridge cases to each other before and after the filing. Then there will be a comparison of the fired cartridge cases from the unaltered breech face to the altered breech face. This filing alternation took about three minutes using a standard file.

Performance Test 5 – 9 mm Sig Sauer, Correlation of 500 Pistols

This test was not performed due to time constraints, however other options are being looked at in order to conduct these tests.

Performance Test 6 – A Large Database Query

This would have taken some test-fired cartridge cases from selected weapons, buried one of the cartridge cases in a large database and then observe the correlation on these cartridge cases. This test could not be performed[1]. Other options are under development to use databases that are not under these constraints.

Performance Test 7 – Breech Face Longevity Study

This test would look at how long a breech face retains its identifying characteristics. Six hundred rounds of ammunition were fired in selected, but unidentified pistols, undergoing SB15 "not unsafe hand gun" testing. Portions of these rounds were collected at regular intervals for testing purposes. These fired cartridges will be correlated to each other to see if there is a longevity effect.

Performance Test 8 – Sub-class Feature Effects on the Breech Face.

This test would have looked at the effect of firearms that have steel inserts in the receiver or slide and are susceptible to sub-class characteristics carry over. This result could negate their usefulness in ballistics imaging. This study would have used H & K and Lorcin type pistols. The study was not conducted due to the length of time it would take to identify such firearms at local agencies and the logistical effort needed to obtain adequate test fired samples. This is a study that should be researched.

Satisfactory performance in these tests will not insure the system is feasible. It would only mean that problems were not predicted within the confines of these very limited tests. On the other hand, if performance is not satisfactory then one could reasonably postulate that an increase in database size would cause even greater problems.

[1] A very limited test using two 9mm Luger pistols was subsequently performed using the NYPD system. This test did not equate to the extensive test proposed in this section.

8.0 PERFORMANCE TEST RESULTS

8.1 Background on Scoring Methodology

The IBIS system used for data entry has a scoring system that aids the examiner in the determination of a possible hit. The breech face image from a cartridge case is separated into two independent components: 1) a breech face image less the firing pin impression, and 2) a firing pin impression image. Each of these images are given a separate correlation score. When an image from a cartridge case is correlated to a database, the computer returns a tabular set of numbers that consist of 1) the most likely match to the cartridge case in the database based on the breech face and its correlation score, and 2) the most likely match to the cartridge case in the database based on the firing pin and its correlation score. Underneath this top row are listed the other candidate hits in order of their correlation scores. What is important to realize is that the score is a relative value and it is only significant for that one correlation. Its value for another correlation may be quite different. This scoring system comes is valuable when there is a significant difference between the top score and the next score. This difference could indicate a good match. If the numbers are close together, the implication is the correlation could not see much difference between the different breech face or firing pin impressions.

In actual practice, it is quite common for the system with a known match to rank either firing pin or breech face #1 and have the other image somewhere in the lower ranking. This difference in ranking scores could be that one of the images did not have enough detail for a good correlation. Likewise, if both breech face and firing pin correlations came up with the same database cartridge in the top ranks, this becomes an indication of a good hit.

8.2 Results of the 50 Random Cartridge Cases – Performance Test 1

Performance Test 1 consisted of 50 Federal cartridge cases that were randomly selected and compared to the 792 Federal cartridge cases that made up the database. As previously mentioned, these cartridge cases were selected because of lot uniformity (all from one manufacturing lot) and the time limitations in purchasing. In essence, the 50 random cartridge cases represented the second test fire[1] of two Federal cartridge cases that were test fired in the 792 CHP pistols. The cartridge cases each had a brass colored primer with a colorless lacquer seal where the primer made contact with the cartridge case. An independent laboratory analyzed a set of 50 cartridges from this lot and confirmed that the lacquer was not on the face of the primer. The only surface on the primer was bare metal.

[1] Most of these pistols were new issue CHP pistols. Prior to this test firing, it is estimated that they had been fired about 30 times in the course of manufacturer and CHP function testing.

One should realize that the following results are based on 792 pistols by one manufacturer. If all new handgun sales require an image, one can expect a substantial increase in the number by a designated manufacturer even in a restricted locality.

The results of this test have been tabulated as percentage hits in three formats: Evidence Cartridge Case Rank in the Database as a function of 1) Either breech face or firing pin, 2) Breech face only, and 3) Firing pin only. Figure 8-1 illustrates these results.

Rank	Breech Face or Firing Pin[2] **# of Cartridges**	Percent in the Rank	Breech Face Only **# of Cartridges**	Percent in the Rank	Firing Pin Only **# of Cartridges**	Percent in the Rank
1	24	48%	13	26%	13	26%
2	3	6%	3	6%	1	2%
3	1	2%	1	2%	1	2%
4	0	0%	1	2%	1	2%
5	0	0%	0	0%	0	0%
6	1	2%	1	2%	0	0%
7	1	2%	0	0%	3	6%
8	0	0%	0	0%	0	0%
9	1	0%	0	0%	2	4%
10	0	0%	0	0%	0	0%
11	0	0%	0	0%	0	0%
12	0	0%	0	0%	0	0%
13	0	0%	1	2%	0	0%
14	0	0%	0	0%	0	0%
15	0	0%	0	0%	0	0%
Higher or Miss	**19**	**38%**	**28**	**56%**	**29**	**58%**

Figure 8-1. Ranking of the 50 random cartridges in the 792-cartridge database.

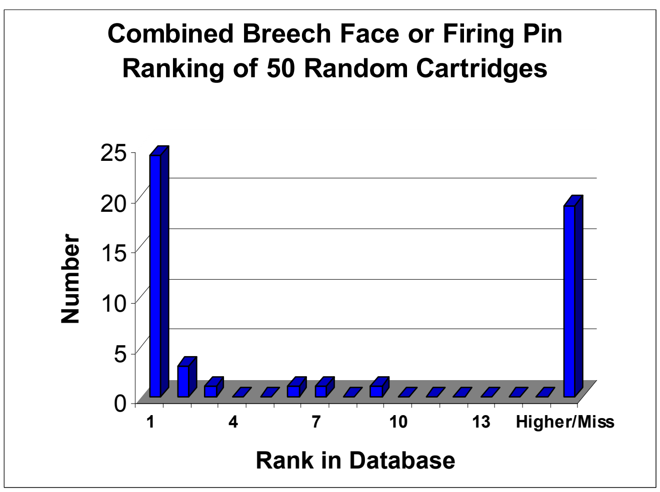

Figure 8-2. Ranking Based on Either Breech Face or Firing Pin

[2] In order to obtain an accurate percentage, once a cartridge case was selected, it was no longer used. The breech face impression was selected first.

The number of cartridges in the ranking are also illustrated in Figures 8-2, 8-3, and 8-4.

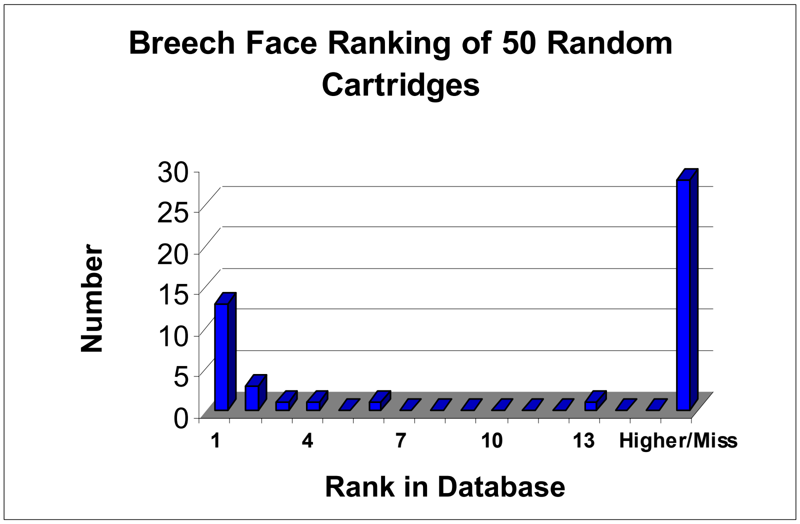

Figure 8-3. Ranking Based on Breech Face Only

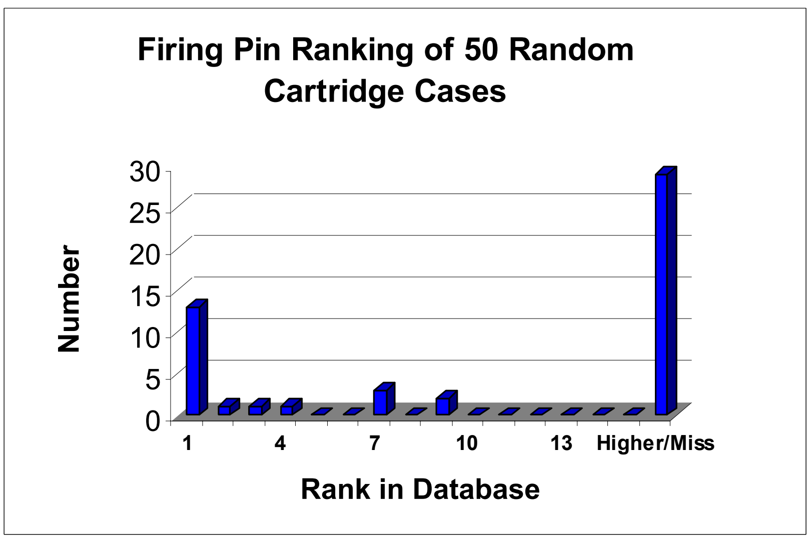

Figure 8-4. Ranking Based on Firing Pin Only

What is interesting about these numbers is that the correlation algorithm, if it finds a candidate match, will generally place it in the first or second rank with substantially lesser amounts in the next 15 ranks. In most cases, by the 10th rank, all cartridge cases that can be identified have been ranked. After this, the rest are essentially unidentified.

In other words, when the algorithm sees sufficient detail, the computer will correlate that impression. Its failure to correlate a particular impression may be attributed to a variety of other factors such as insufficient detail, lack of reproducible marks, or an inability to detect very fine striae. Regardless of these results, this is one of the problems with firearms evidence in general. Microscopic striations do not always mark in a consistent and reproducible manner. Firearm identifying characteristics are not like fixed DNA or fingerprint data that remain unchanged. Ideally, one would like to have both the breech face and firing pin in the first few ranks. This would be a clear indication of a good match. In this test, about 11 (22%) of the 50 samples had both scores in the first 15 ranks. This means the examiner would have to carefully evaluate the images to see if there is enough information to warrant further identification work in the other hits. Keep in mind that all cartridge cases will be ranked whether they match or not. The score by itself is only a good indicator when there is a noticeable difference between two adjacent scores that are near the top.

While only 50 of the 792 cartridge cases were tested in this manner, their random selection is statistically significant enough to state that if all the cartridge cases were tested, the result would be essentially the same under these conditions. Thus, given the same ammunition for comparison, the system will miss about 38% of the time when either a breech face or firing pin is used as a ranking score. Performance Test 1B shows that if a cartridge case is to be detectable in the top 15 of a much larger database, it is almost essential that the cartridge case score in the first rank of the current database.

8.3 Correlation Item versus Database Size - Performance Test 1B

Four evidence cartridge cases (designated E8, E2, E30 & E44) were initially selected and used to correlate against the various sizes of the 792-cartridge case database. After three tests, it became obvious a fourth test was not needed. This test was an attempt to predict the correlation time as the database increased in size. The correlation works has an initial variable time curve that reaches its maximum after an initial set of cartridge cases has been correlated. After this, the correlation time increases linearly with time. The reason is that the algorithm correlates the first 100 samples. After that, it correlates the top 20 %. The computers used for this correlation were a sophisticated array consisting of a Linux based COMPAQ developmental server and four dual Pentium stackable industrial computers, each with 256 MB of RAM. The results of the correlation times are listed in figure 8-5.

Sample	DB Size=100	DB Size =250	DB Size =500	DB Size =792
E8 - CA27[3]	29 sec	40 sec	43 sec	49 sec
E2 - CA457	33 sec	40 sec	47 sec	51 sec
E30 - CA30	29 sec	43 sec	48 sec	51 sec

Figure 8-5. Correlation Times as a function of Database (DB) Size

The data was also plotted and illustrated in figure 8-6 along with the linear regression curve and its results. A modified regression analysis unit, R^2 indicates the goodness of fit of the E8 data to the linear regression curve. A value of 1 is ideal; thus in this context a value of 0.87 indicates a reasonable fit of the data to the linear regression

[3] E8 – CA27 Refers to a evidence cartridge case (E8) run against its counterpart in the database CA 27

curve. Based on this plot, a database of 10,000 cartridges might take 316 seconds or about 5 minutes per cartridge case to correlate.

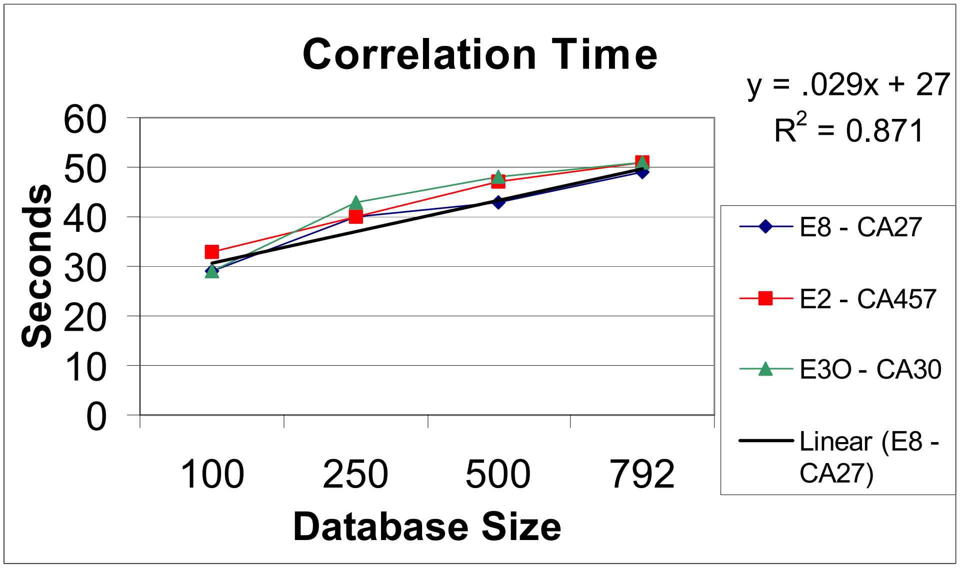

Figure 8-6. Correlation Times as a Function of Database Size

The results of this study indicate that correlation times are not a significant issue for a large database. This assumes that such correlations do not have to be run in real time. In fact, there are no pressing reasons to have them run in real time except under the most unusual circumstances. FTI appears to have scalable computer hardware that can accommodate large databases with minimal problems.

8.4 Correlation Ranking Position as a Function of Database Size – Performance Test 1C

This test was a two-fold test, one to retest a portion of Performance Test 1 (the 50 random cartridge cases), and the other to test the effect of database size on the ranking of a cartridge case. To accomplish this, five cartridge cases from Performance Test 1 (E2, E8, E30, E44, E21) were imaged by another operator as E149A to E153A. In this case, the ranking of some of the cartridge cases actually changed from the ranking in Test 1. Sometimes the ranking improved and sometimes it became worse. This change primarily affected cartridge cases that had ranking in the 20th or higher rank. These results again confirmed that the most significant scores for IBIS are in the first 15 rankings.

Ideally, more data should have been run with this test and it would have been nice to include this data in an existing database to increase the noise factor. Likewise it would have been better to select cartridge cases that ranked 6-10 in the 792 cartridge case database. Unfortunately, there were very few at this level and they did not stand out when the quick selection was made for this test. However, there are some indications that appear to predict what will happen to a ranking (other than a 1st rank position) when the database increases in size.

If the specimen ranks 5 or better (i.e. E12) at a database size of 100, it will only increase its ranking slightly as the database increases to 792 cartridge cases. If the initial ranking is higher than 5 in a database of 100 (i.e. E30, E21, E8), there is a significant degradation as the database increases to a size of 792.

Database Size Correlation									
Ev. #	EV. #	100	200	300	400	500	600	700	792
E151A	**E-30**	**7**	**7**	**8**	**11**	**17**	**19**	**26**	**24**
E153A	**E-21**	**5**	**5**	**6**	**10**	**11**	**12**	**15**	**15**
None	**E-8**	**7**	**6**	**8**	**8**	**11**	**17**	**27**	**30**
None	**E-12**	**2**	**2**	**3**	**3**	**3**	**3**	**4**	**6**

Figure 8-7. Selected Examples of Ranking and Database Size

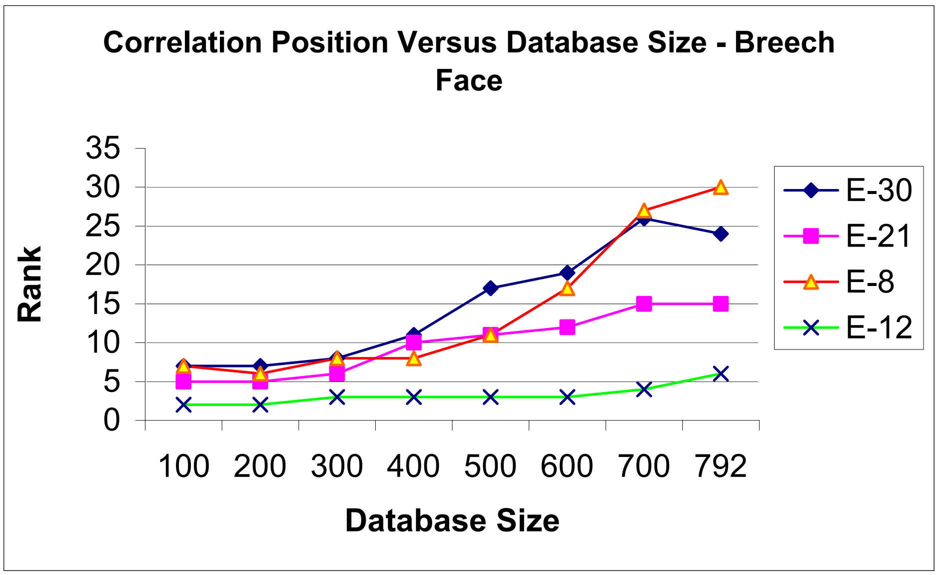

Figure 8-8. Graphical Representation of Ranking and Database Size

A linear regression analysis of E30 indicates a modified R^2 value of .918 with an approximate linear equation of Y=.0301X + 1.3. Hypothetically, E30 could end up in rank 300 if the database were to increase to 10,000 cartride cases. This again illustrates the importance of the algorithm in the first or second rank. If this correlation picks a good match from rank 1 or 2, it appears to stay there as the database increases seven fold in size.

8.5 Firearms Not in the Database – Performance Test 2

Ten cartridge cases were obtained from pistols not in the database. These ten cartridge cases were compared to the 792-cartridge case database to see how they ranked.

The first choice for the breech face ranking was completely different from the first choice for the firing pin rankings. An attempt to evaluate the scoring system was not useful since some of these cartridge cases had scores similar to Test 1, wherein they made positive identifications in the first ranking. As FTI has mentioned, a score is only relevant within a particular correlation. The score cannot be used to compare the ranking of two correlations. In retrospect, one should look to see if the firing pin correlation is within 15 positions of the breech face correlation and the scoring itself to see if there were significant gaps. On a couple of selected samples, it appeared the scoring did not change significantly between the first and second ranking. None of these went in the first 15 ranks and would not be subject to false identification.

8.6 Ammunition Effect on Correlation – Performance Test 3

In this test, 22 random CHP pistols were used to fire five different brands of .40 S&W ammunition. The ammunition consisted of cartridges with headstamps of Remington, Winchester, Armscor, Cor-Bon, and Eldorado. These cartridges were fired at the same time as the reference Federal cartridges. Different manufactures use primers that may be different in composition, finish, shape and seating depth. These changes can cause an apparent difference or lack of substantial detail in breech face marks. One of the key axioms in firearm examinations is to try to use the same ammunition for comparison as the evidence specimen. This data set consisted of 72 evidence cartridge cases that were compared to the 792 – CHP cartridge case database.

Figure 8-9 illustrates the profiles for 1) Breech Face or Firing Pin, 2) Breech Face, and 3) Firing Pin. Ideally one would like to have a single cartridge case rank high in both the breech face and firing pin profiles.

Rank	Breech Face or Firing Pin	Percent in the Rank	Breech Face	Percent in the Rank	Firing Pin	Percent in the Rank
1	16	22.2%	11	15.3%	6	8.3%
2	2	2.7%	0	0.0%	2	2.8%
3	1	1.4%	0	0.0%	3	4.1%
4	1	1.4%	0	0.0%	1	1.4%
5	1	1.4%	1	1.4%	0	0.0%
6	0	0.0%	0	0.0%	0	0.0%
7	0	0.0%	0	0.0%	1	1.4%
8	0	0.0%	0	0.0%	0	0.0%
9	0	0.0%	1	1.4%	0	0.0%
10	0	0.0%	0	0.0%	0	0.0%
11	0	0.0%	0	0.0%	0	0.0%
12	0	0.0%	0	0.0%	1	1.4%
13	3	4.2%	2	2.8%	2	2.8%
14	3	4.2%	1	1.4%	2	2.8%
15	0	0%	0	0%	0	0%
Higher/ Miss	**45**	**62.5%**	**56**	**77.7%**	**53**	**73.6%**

Figure 8-9 Summary Data of the Effect of Different Ammunition

The corresponding graphical displays are illustrated as figures 8-10 to 8-12.

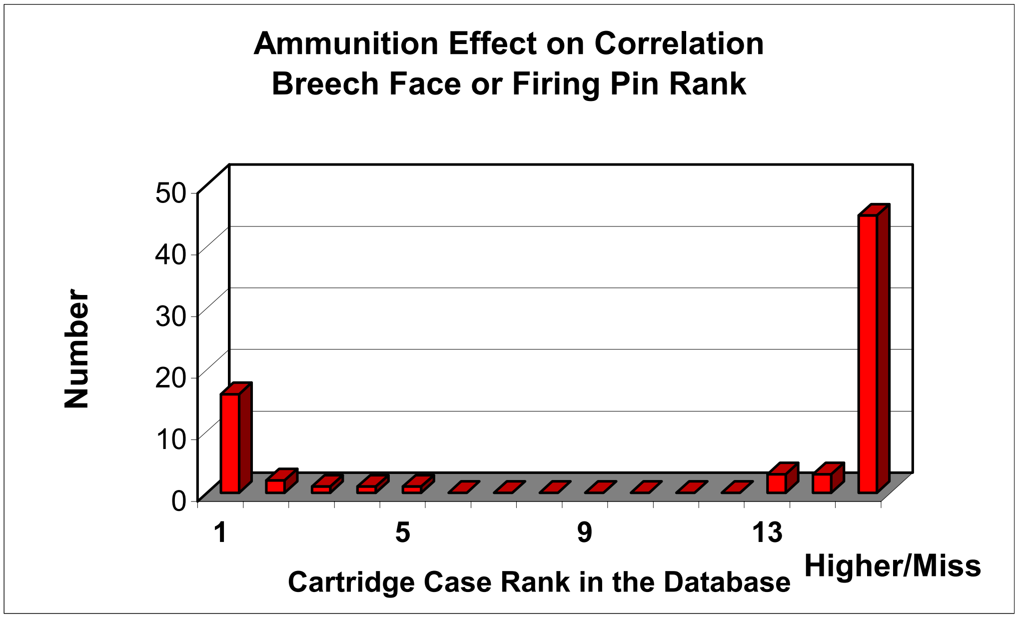

Figure 8-10. Plot of the Ranking for Either Breech Face or Firing Pin Impressions

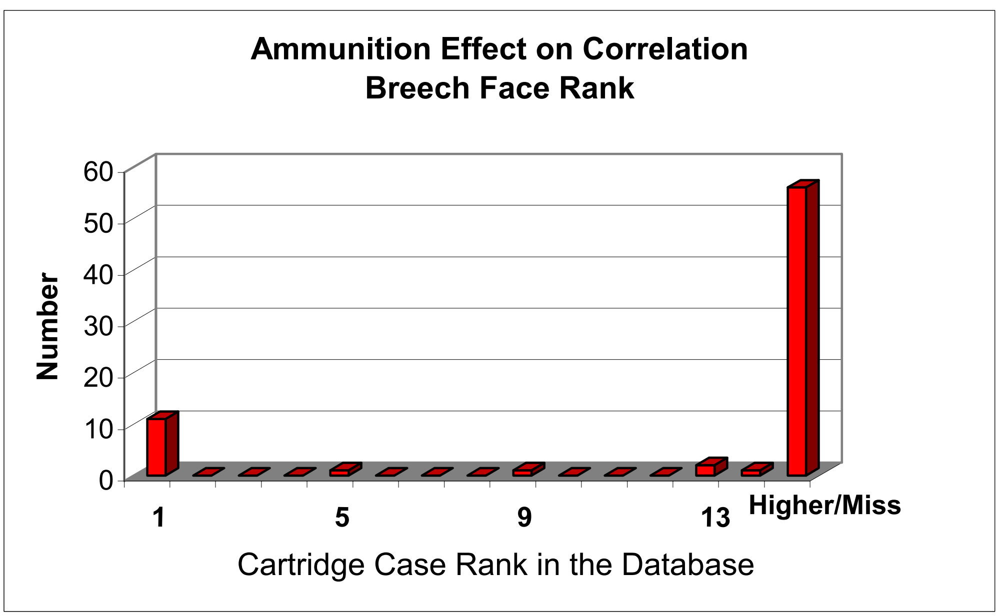

Figure 8-11. Plot of the Ranking for Breech Face Impressions Only

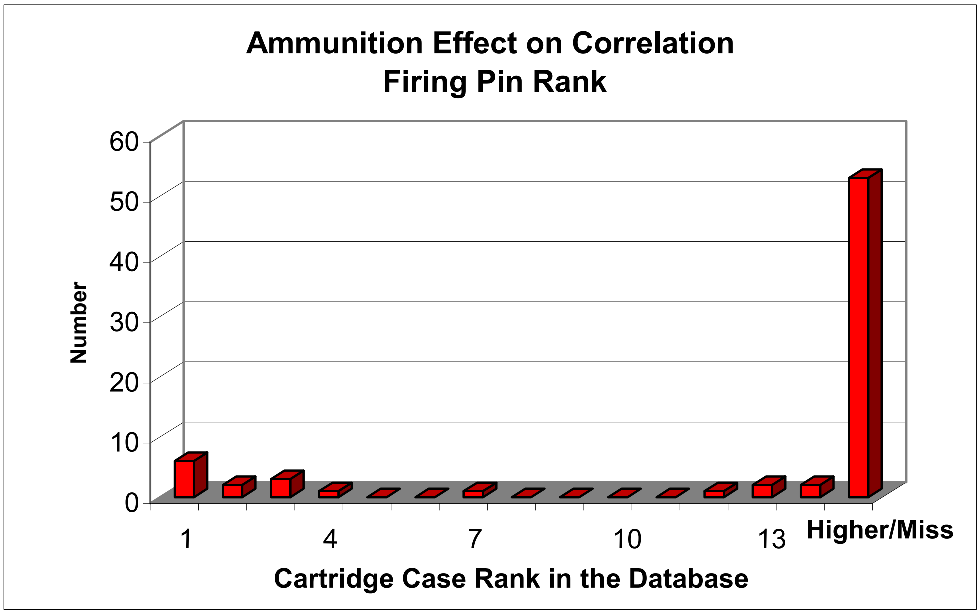

Figure 8-12. Plot of the Ranking for Firing Pin Impressions Only

The number of evidence cartridge cases that ranked in the top 15 positions for both the breech face and firing pin impressions was 8 for a rate of 11%. One (1) cartridge case or 1.4 % ranked in the 1st position for both breech face and firing pin impressions.

This test demonstrates the potential problems when different brands of ammunition are used and compared to that in the database. These differences can be attributed to a host of factors such as primer hardness, primer seating depth, chamber pressure, lacquer coating, etc. It is not necessarily the fault of the correlation algorithm because if a breech face marks differently, one cannot expect an algorithm to make that association. On a local level with current databases, it is also an issue, but the database size for a given manufacturer is much smaller. With a statewide database, even if it was set to search only a local area, one can readily expect a ten-fold increase in firearms by any one manufacturer.

8.7 Altered Breech Face - Performance Tests 4

One CHP pistol was test fired with two Federal cartridges (CA 752 and E 123). After this, the breech face and firing pin were altered by a light filing operation which took less than five minutes. A second set of test fires where then made and labeled as CA 753 and E124.

- CA 752 correlated to E123 in the first rank for both firing pin and breech face and it could not find E124.
- CA 753 correlated to E124 in the 35th rank for breech face and 1st rank in firing pin. It could not find E123.

These are normal and expected results. Changing the topography of a breech face or firing pin will change its identity.

8.8 9 mm Sig Sauer Correlation of 500 9 MM Pistols - Performance Test 5

This test was not performed at this time.

8.9 Large Database Query - Performance Tests 6

This test could not be performed at this time. Other options are under consideration.

8.9.1 Limited New York Police Department Study - Large Database Query.

The New York Police Department (NYPD) was asked to evaluate a series of 9 mm cartridge cases fired from two (2) "evidence" Sig Sauer pistols in custody of the California Criminalistics Institute (CCI). The first Remington Peters cartridge case was to be the evidence cartridge case and the remaining cartridge cases were to be compared to this specimen in the NYPD database of 3,673 evidence 9 mm cartridge cases. The following cartridges were fired from two Sig Sauer P226 pistols labeled A and B:

- 2 - Remington Peters (# 1 and 2)
- 1 – Winchester (#3)
- 1 – Federal (#4)
- 1 - Hornady Vector (#5)
- 1 – Fiocchi (#6)
- 1 – CCI (#7)
- 1 - Sellier & Bellot (#8)

For pistol A, four of the remaining seven cartridge cases were found in the first 15 positions (breech face or firing pin impression).). Cartridge case A2 ranked in the 1st position for both breach face (BF) and firing pin (FP). Cartridge caseA3 ranked in the 1st position for the FP and cartridge case A6 ranked in the 1st position for BF. For Pistol B, four of the remaining seven were in the first 15 positions (breech face or firing pin impressions). Cartridge B2 and B6 ranked in the 1st position for FP. In general, cartridges 5, 7 and 8 seemed to be the most difficult for comparison.

NYPD personnel also evaluated the matches for these cartridge cases and in most cases found that there were marginal or no marks on the breech face or firing pin impressions for those cartridge cases that could not be linked. However, there were other marks (not amenable to database entry) that could be compared.

This illustrates the effect that changing ammunition has on the reproducibility of identifying marks as well as the variability within the same model firearm. Though more difficult with pistol B, in both of these cases, ammunition by the same manufacturer was identifiable. An intercomparison of all cartridges A1-A8 and B1-B8 to each other yielded somewhat better results.

8.10 Breech Face Longevity Study - Performance Test 7

Two sets of .40 S&W cartridge cases were obtained from an independent testing laboratory certified by the State of California to conduct handgun test in compliance with California law. One set was fired by a Glock type pistol using CCI brand cartridges. An unknown pistol using IMI brand cartridges fired the other set. These sets contained fired cartridge cases sampled at intervals of 1-6, 101-106, 201-206, 301-306, 401-406, 501-506, and 595-600. One cartridge case from each interval was entered as a Test (CA793 - CA806) and another cartridge from each set was entered as evidence (E125 – E138). The intent was to correlate the results to see if the cartridge cases fired later would rank sequentially in order to the first test fired cartridge case of the series.

Because of the fact that the cartridge cases had different overall shapes, it would have been better to conduct this test in a real time database. The Glock type CCI cartridge cases (E125-E131) were going to be tested in the FTI Glock 500 cartridge case database, but on the last day the computer was in the process of being relocated and the cartridge cases could only be run against themselves. The CCI cartridge cases are sufficiently different from the CHP cartridge cases. Thus they also would have benefited from comparison in an actual large database. The results are depicted in Appendix C Performance Test Numerical Results. Figure 8-13 illustrates a partial result for the breech face correlation of non-Glock type breech faces. With the exception of E133, all cartridge cases were matched with the CA800-806 test fires from a series of 600 cartridge cases. Ideally, one would expect to see the breech face position of E133-E138 relative to CA800 increase as the higher E series are correlated.

Evidence Number	CA #	Item Description	Cartridge Manufacture	Breech Match To	Breech Rank in 40 S&W DB	Breech Position relative to CA XX	DB Size
E132	800	IMI 0-5	IMI - FP Drag	CA800	1	CA800=na	806
E133	801	IMI 100-105	IMI - FP Drag	CA82	42	CA800=Not in List	806
E134	802	IMI 200-205	IMI - FP Drag	CA135	5	CA800=2	806
E135	803	IMI 300-305	IMI - FP Drag	CA804	10	CA800=8	806
E136	804	IMI 400-405	IMI - FP Drag	CA805	2	CA800=3	806
E137	805	IMI 500-505	IMI - FP Drag	CA801	10	CA800=33	806
E138	806	IMI 595-600	IMI - FP Drag	CA801	11	CA800=27	806

Figure 8-13. Correlation of Longevity Results for Breech Face IMI Cartridges

There is some indication that this is happening with E137 – E138 where the ranking of these increased when compared to CA800. However, the results are not linear. There is definitive ranking degradation of E133-138 (Figure 8-13) when compared to CA 800. Further tests need to be conducted in this area. Ideally, the same pistol that makes up the test database and ranks about 5 or better should be used in future tests.

8.11 Sub-Class Feature Effects on the Breech Face.

This test was not performed at this time.

8.12 Discussion and Interpretation

In this study we looked at the ranking of the top 15 cartridges cases images. In actual practice, the IBIS operators are trained to look at only the top ten cartridge case images. Furthermore this was not a true blind study. We identified the cartridge case image results from a predetermined list. That is, the operator was not required to identify a cartridge as a candidate. If the operator had been required to make a decision as to which cartridge cases images were candidates for the first fifteen positions, then the number of hits would most certainly have been lower.

The implications of this study using the 792 CHP pistols should not be limited to just the CHP pistols studied. This pistol database was used to predict what could happen in a larger database. Ideally, after these initial tests, the CHP database should be mixed with a larger database of different firearms. These studies show that when a match is made with the algorithm, the result will tend to cluster in the top 1-5 positions. Furthermore, if a match ranks in the top 1or 2 positions it has a tendency to stay in that ranking as the database size increases from 100 to 792 pistols. By the same token those that are in greater ranks do show a gradual decline in position as the database size increases. Thus one could infer that any of those cartridge cases that were in ranks 3 or greater probably would not be detected in the first 50 ranks if a database of similar impression evidence increases to 10,000. In reality, it appears that the cartridge case has to rank in the 1st or 2nd place in the CHP database in order to be detectable in a much <u>larger regional database</u> of registered owners. This occurred about 22% of the time for either a breech face or firing pin hit.

8.12.1 Both Images in the Top Ranks

The issue of ranking in the 1st position for both firing pin and breech face impressions versus ranking in the 1st position in either breech face or firing pin impressions can have significant time implications. If both the breech face and firing pin impressions show up in the first fifteen ranks, then one can feel confident in submitting the selected cartridge case for further optical analyses and confirmation. When using different ammunition, 11% of the time both breech face and firing pin images were in the top 15 ranks of the database and 1.4% of the time cartridge cases with both impressions were in the 1st rank.

8.12.2 One Image in the Top Rank

In looking at either the ranking of the breech face or firing pin impressions, one has to realize that about 89% of the time the system does not give a clear indication of what may be a match (unless there is a significant difference in match score). In each of those cases the examiner will have to closely look at the digital images to determine if there is a match or not. The examiner will have greater difficulty reviewing firing pin impressions and an easier time with breech face impressions. Intuitively, breech face impressions are easier to evaluate. In this study involving different ammunition types, 15.3% of the breech face impressions were in the 1st rank. Overall, 22% of the time the matching breech face impression was in the top 15 positions of the CHP database. In these cases, it will be important to properly identify the candidate matching cartridge case from the digital images in the database because subsequent optical comparisons take quite a bit of time.

8.12.3 Estimate of Percent Hit for a Large Regional Database

Comparing the results were either the firing pin or breech face image correlation is in the first rank (Performance test 3) and the correlation effect on database size (Performance test 1C), it is obvious that one will have to use the hit percent for the first rank when applying this study to larger databases. The correlation tests indicate that when a database size is increased, those cartridge cases not in the first ranks will drop in identification value. Thus if a database is expanded to a very large database, then the actual percentage of correct hits may be 1.4% for the situation where both breech face and firing pin impressions are in the first rank. Likewise, the correct hit percentage may be 22% for those cases where either the firing pin or breech face impression are in the 1st position. The other issue is that the system would miss 78% of the cartridge cases that have a counterpart in the database.